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OIL SHALE TRACT C-b

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FIRST YEAR
ENVIRONMENTAL BASELINE PROGRAM

ANNUAL SUMMARY
AND TRENDS REPORT

(November 1974 Through October 1975)

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C-b SHALE OIL PROJECT

Ashland Oil, Inc.
Shell Oil Company, Operator

ID 88057496

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C3712
1975
C.3

U. S. DEPARTMENT OF THE INTERIOR

PROTOTYPE OIL SHALE LEASING PROGRAM

OIL SHALE TRACT C-b

FIRST YEAR ENVIRONMENTAL BASELINE PROGRAM

ANNUAL SUMMARY AND TRENDS REPORT

November 1974 Through October 1975

Submitted to:

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Area Oil Shale Supervisor
Conservation Division
U. S. Geological Survey
Grand Junction, Colorado

By:

C-b Shale Oil Project

Ashland Oil, Inc.
Shell Oil Company, Operator

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February 25, 1976

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TRACT C-b
ANNUAL SUMMARY AND TRENDS

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

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LIST OF FIGURES

LIST OF FIGURES
(Continued)

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United States Department of the Interior

GEOLOGICAL SURVEY
Conservation Division
Area Oil Shale Supervisor's Office
Mesa Federal Savings & Loan Bldg.
131 N. 6th - Suite 300
Grand Junction, Colorado 81501

March 9, 1976

Memorandum

To: Executive Director, Oil Shale Environmental Advisory Panel

From: Area Oil Shale Mining Supervisor

Subject: C-b "First Year Environmental Baseline Program, Annual Summary and Trends Report"

The C-b Shale Oil Project is making available to you by direct shipment 50 copies of the subject report for your information and for distribution to the members of the Oil Shale Environmental Advisory Panel. The report is being provided to aid in review of the C-b Detailed Development Plan. The report covers all environmental baseline programs including geology, hydrology and water quality, meteorology and air quality, biotic communities, soil survey and productivity assessment, and scenic and archaeological values. Based on the results of these studies, and evolving conceptualization of ecological interrelationships has been developed and is included in the report. This report relates directly to and expands on Volume II of the C-b DDP --- "Summary of First Year's Environmental Baseline Programs and Environmental

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LIST OF TABLES

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I. INTRODUCTION

This report summarizes results of the first year of the Environmental Baseline Program on Tract C-b located in the Piceance Creek Basin of Rio Blanco County in western Colorado.

Four venture partners participated in Tract C-b during the first year of the environmental baseline period: Ashland Oil, Inc., Atlantic Richfield Company, Shell Oil Company and The Oil Shale Corporation. The Atlantic Richfield Company was the Operator from Project inception early in 1974 until July 1, 1975 when Shell Oil Company took over as Operator.

Effective December 31, 1975 Atlantic Richfield Company and The Oil Shale Corporation terminated their participation in the C-b Shale Oil Project. Ashland Oil, Inc. and Shell Oil Company are continuing the project with Shell Oil Company as the Operator. They intend to complete the two-year environmental baseline program and have submitted the Detailed Development Plan in order to proceed with the approval process. Some activities, however, are being postponed pending clarification of a number of problems which stand in the way of oil shale development.

Tract C-b is governed by the terms and conditions of The Federal Oil Shale Prototype Leasing Program as administered by the Area Oil Shale Supervisor's Office (AOSSO), U. S. Department of the Interior, Geological Survey, Grand Junction, Colorado, under the supervision of Mr. Peter Rutledge.

The location of Tract C-b is shown in Figure I-1 and contains the following lands:

Township 3 South, Range 96 West, 6th Principal Meridian
- Sec. 5: W½ SE¼, SW¼;
- Sec. 6: Lots 6 and 7, E½ SW¼, SE¼;
- Sec. 7: Lots 1, 2, 3, 4, E½ W½, E½;
- Sec. 8: W½ NE¼, NW¼, S½;
- Sec. 9: SW¼;
- Sec. 16: NW¼, W½ SW¼;
- Sec. 17: All;
- Sec. 18: Lots 1, 2, 3, 4, E½ W½, E½.

Township 3 South, Range 97 West, 6th Principal Meridian
- Sec. 1: S½;
- Sec. 2: SE¼;
- Sec. 11: E½;
- Sec. 12: All;
- Sec. 13: N½;
- Sec. 14: N½ NE¼.

Lease Stipulations specifically require the collection of environmental baseline data for a period of at least two consecutive full years, one full

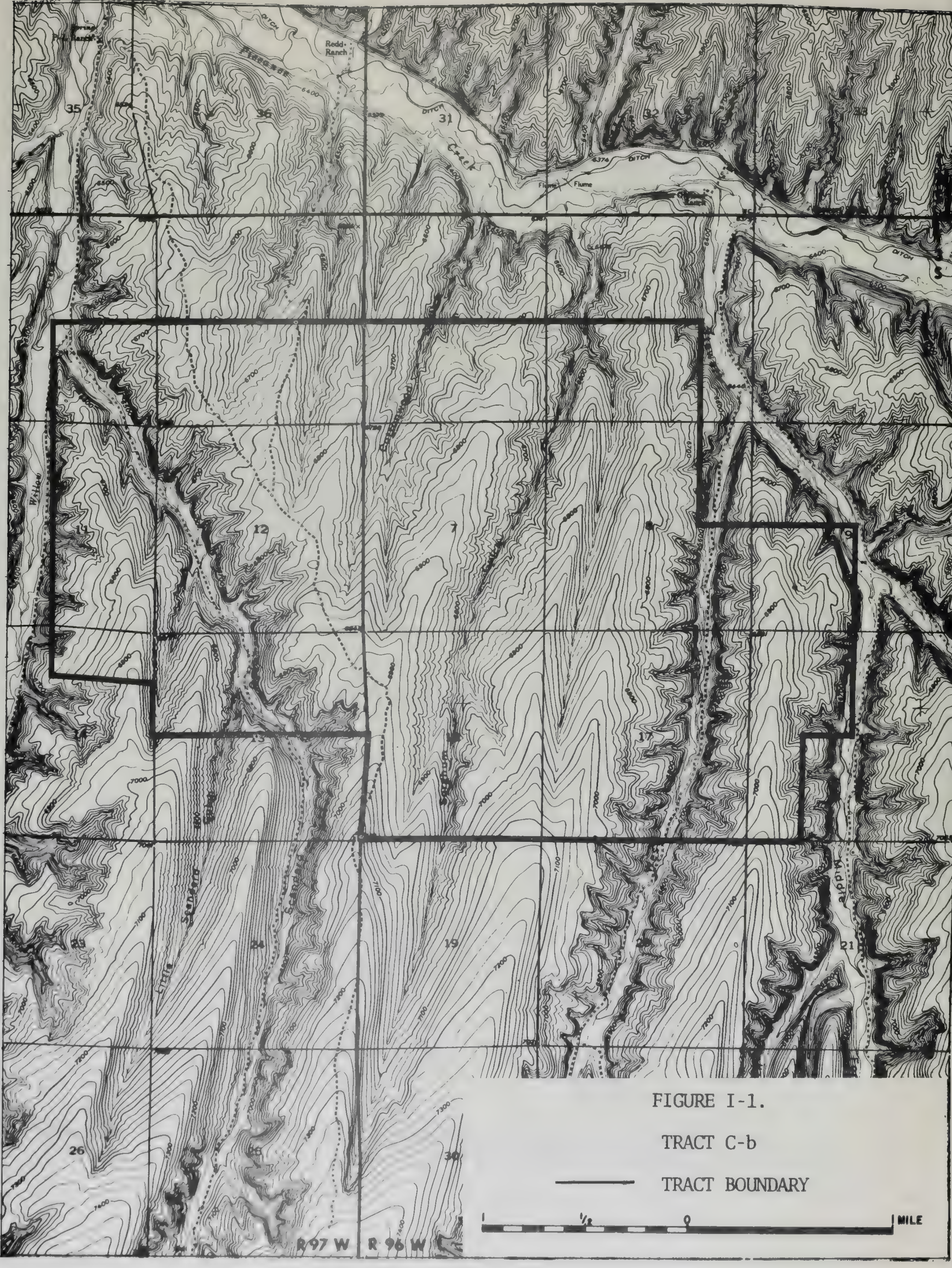

FIGURE I-1.

TRACT C-b

year of which shall be prior to the submission of the detailed development plan also required by this lease. Development of the oil shale facility can proceed only after approval of the detailed development plan by the Area Oil Shale Supervisor.

The nominal "first" year reported herein is from November 1, 1974 through October 31, 1975. However, some of the subprograms started prior to this date, so minor deviations about the nominal dates are to be expected and are reported.

The lease stipulations require environmental baseline data collection and analysis in the following areas: surface water, ground water, air quality, flora and fauna, soil survey and productivity assessment and archaeology. In addition to the above basic areas the C-b Project feels reporting should include 1) our conceptualization of the ecological interrelationships that exist on the Tract, both to help guide the future monitoring program and to obtain a better understanding and quantification of potential environmental impacts and 2) a discussion of the type and quality of the scenic resources of the Tract area. To reflect these considerations this annual summary is organized as follows: Chapter I contains the introduction, Chapter II discusses the geology of the Tract, Chapter III contains hydrology and water quality, Chapter IV discusses air quality, Chapter V discusses the biotic (floral and faunal) communities, Chapter VI discusses soil survey and productivity assessment, Chapter VII discusses the evolving conceptualization of ecological interrelationships, Chapter VIII scenic and archaeological values and Chapter IX the literature cited. In each discipline the program description, the data obtained, data quality and the interpretations of results are presented.

The reader should be aware that details of this work are reported in quarterly data reports submitted to the Area Oil Shale Supervisor's Office. These reports are available in that office for public review and inspection. Furthermore, each data report is summarized in a quarterly summary report which is also available for public review and inspection. Five quarterly data and summary reports have been submitted to date.

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II GEOLOGY

A. Program Description

1. Surface Geologic Mapping

A surface geologic mapping program was conducted on Tract C-b to determine the distribution of stratigraphic units and structural features and to identify areas of geologic hazards. Preliminary work consisted of office photogeologic studies which utilized color (vertical and oblique), infrared and black and white aerial photography to define lineations and possible mapping units. Field mapping was done on color photographs at a scale of 1" = 567' and compiled on 7½ minute U.S.G.S. topographic maps which were enlarged to a scale of 1" = 1000'. Thirteen detailed stratigraphic sections were measured. Joint sets were measured at 82 locations on and off the Tract.

2. Core Drilling

Exploratory drilling was conducted on Tract C-b to acquire geologic information and fundamental data on ground water. Seven vertical holes were cored continuously from above the Mahogany zone to below the R-4 zone. Oriented cores were obtained from the surface to below the Mahogany zone in four slant holes. Data from 14 holes which were drilled primarily for hydrological purposes and seven coreholes that were drilled on the C-b Tract before the Lease was granted were also used to develop the geologic framework of the Tract. The locations of these holes are shown on Figure II-1. The zones penetrated and cored in the holes are shown on Figures II-2 and II-3.

A modified Fisher assay was run on all cores on one-foot intervals. The cores were analyzed for sodium and alumina content in the R-4 zone and for alumnia content only in the Mahogany zone on one-foot intervals. The occurrence of arsenic, antimony, boron, cadmium, fluoride, mercury and selenium was determined on samples from four holes that represented the section of rock from the surface to below the R-4 zone.

A summary of the information that has been obtained from the exploratory drilling program and which is included in quarterly reports is shown in Table II-1.

B. Structure

Tract C-b is located in the southeastern part of the Piceance Creek Basin on the southern flank of the Hunter Creek Syncline (Figure II-4). As shown in Figure II-4, the axis of this east-west trending structure is immediately north of the northern boundary of the Tract. Beneath the Tract, the beds strike approximately east-west and dip uniformly toward the north at a rate of about 150 feet per mile.

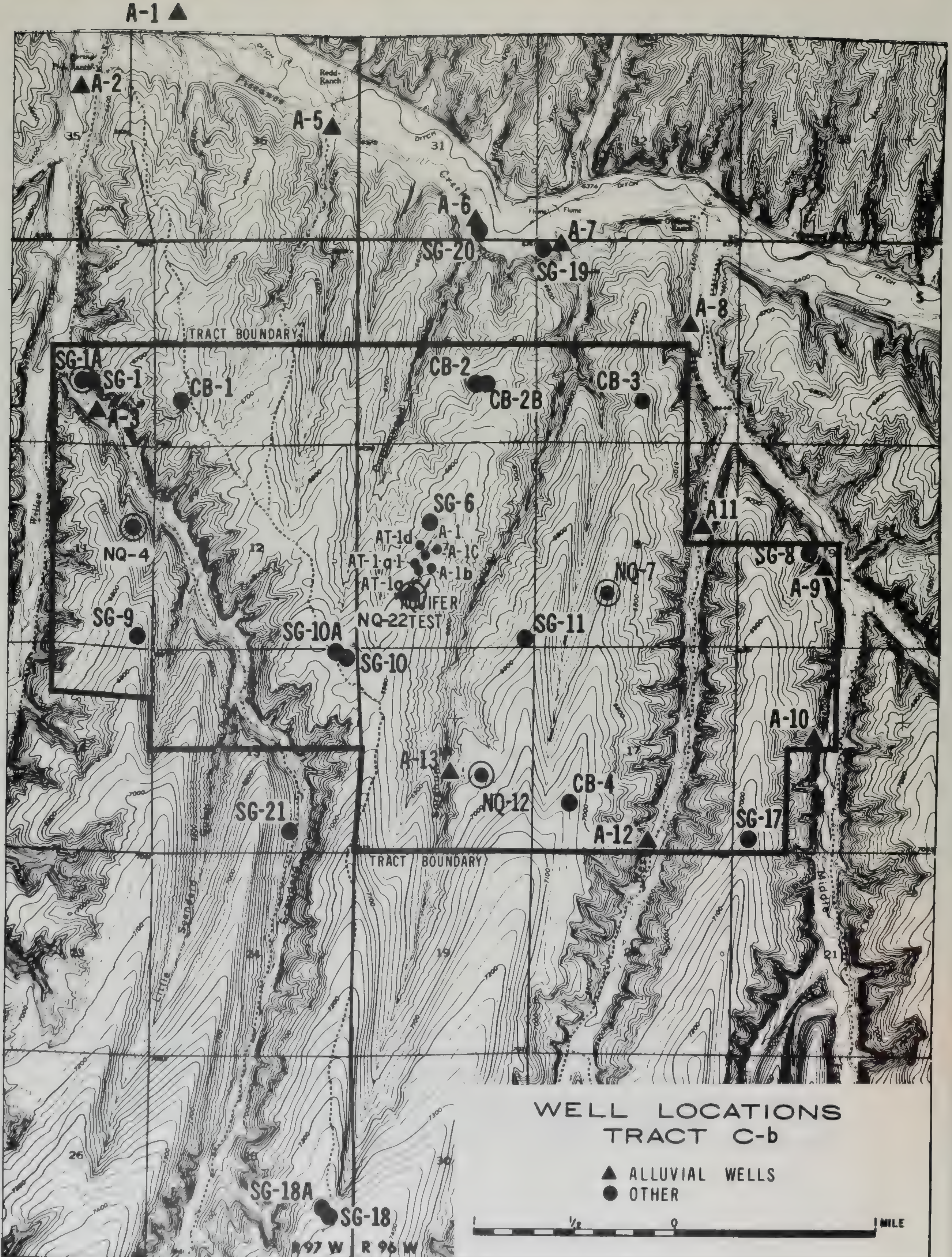

WELL LOCATIONS
TRACT C-b
ALLUVIAL WELLS
OTHER
MILE
TRACT BOUNDARY
A-1
A-2
A-3
A-5
A-6
A-7
A-8
A-9
A-10
A11
A-12
A-13
SG-1A
SG-1
SG-6
SG-8
SG-9
SG-10A
SG-10
SG-11
SG-17
SG-18A
SG-18
SG-19
SG-20
SG-21
CB-1
CB-2
CB-2B
CB-3
CB-4
NQ-4
NQ-7
NQ-12
NQ-22TEST
AQUIFER
AT-1d
AT-1a-1
AT-1a
A-1
A-1C
A-1b
R 97 W
R 96 W

FIGURE II -1

Figure II-2

C—b TRACT
DRILLING SUMMARY

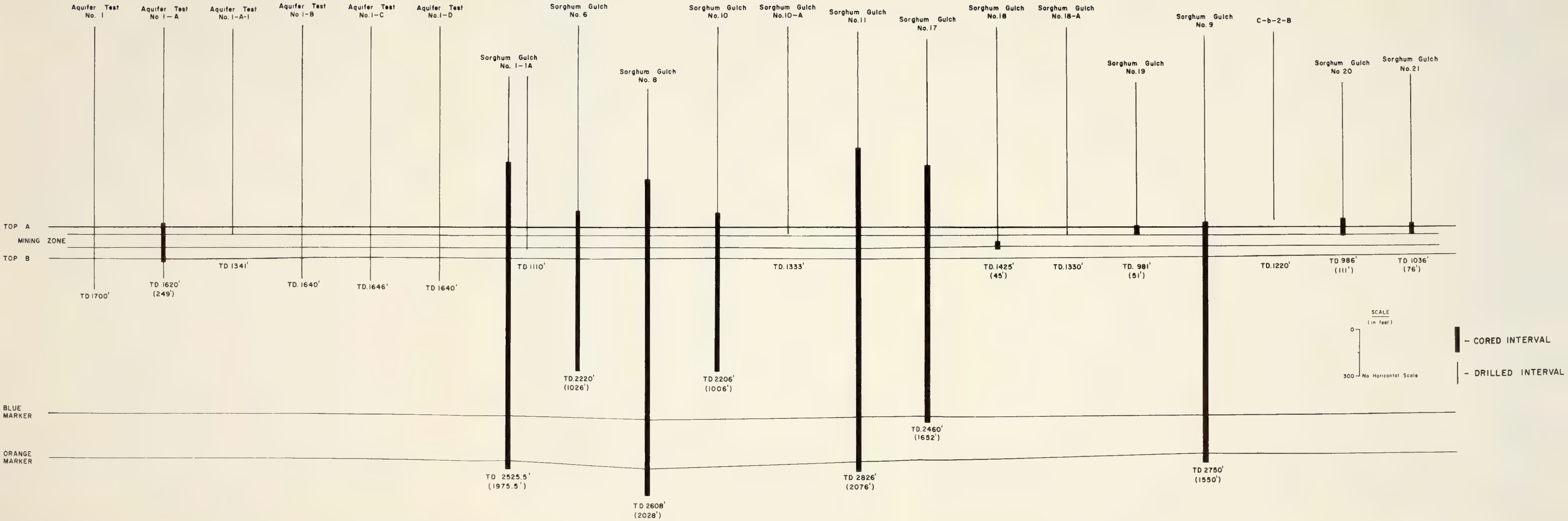


FIGURE II-3

TRACT C-b DRILLING SUMMARY

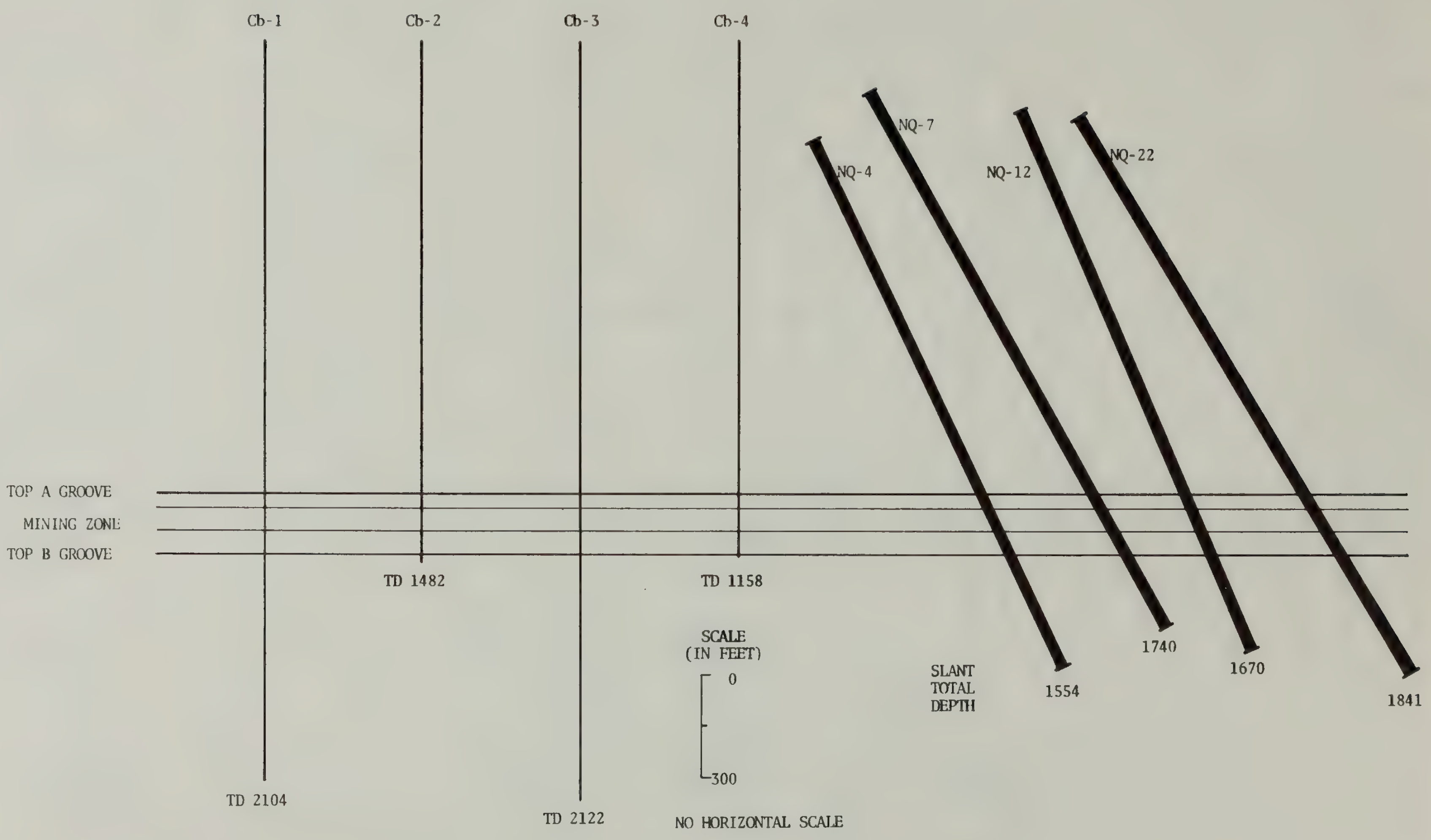


TABLE II-1
WELL SUMMARY TABLE

1. Well Designation	AT-1	AT-1a	AT-1a1	AT-1b	AT-1c	AT-1d	SG-1	SG1a	SG-6	SG-8	SG-9	SG-10	SG-10a	SG-11
2. Well Type	AT	AT (CH)	AT	AT	AT	AT	CH	GHT	CH (AT)	CH	CH	CH (AT)	GHT	CH (AT)
3. Completion Date	1/23/75	7/1/74	7/10/74	7/20/74	8/18/74	7/28/74	12/6/74	2/7/75	8/22/74	11/27/74	10/23/74	6/29/74	7/10/74	9/8/74
4. Total Depth (Geolograph) (feet)	1700	1621	1341	1638	1640	1640	2525	1180	2220	2608	2750	2211	1333	2826
5. Water Data														
a. Drilling Water Production	C1Q 2Q	C1Q	C1Q	C1Q	C1Q	C1Q	C2Q	C2Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q
b. Drilling Water Samples (# taken)	1	4	NA	NA	4	NA	7	NA	5	7	5	4	NA	25
c. Water Quality Analyses	C1Q 2Q	C1Q			C1Q		C2Q		C1Q	C2Q	C1Q	C1Q		C1Q
6. Aquifer Data														
a. Drill Stem Tests		C1Q			C1Q		C2Q C3Q			C3Q		C1Q		
b. Jetting Tests	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C2Q	C3Q	C1Q		C1Q	C1Q	C1Q	C1Q
7. Geophysical Logs,														
a. Schlumberger (1) Borehole, Compensated Sonic	C1Q	*		C1Q	C3Q	C1Q	C2Q		C3Q	C2Q	C2Q	*		C1Q
(2) Laterolog	C1Q	*		C1Q	C3Q	C1Q	C2Q		C3Q	C2Q	C2Q	*		C1Q
(3) Formation Density	C1Q	*		C1Q		C1Q	C2Q	C2Q		C2Q	C2Q	*		
(4) Compensated Neutron Formation Density		*		C1Q	C3Q	C1Q			C3Q			*		
(5) Temperature	C1Q	C1Q		C1Q	C3Q	C1Q	C2Q		C3Q	C2Q	C2Q	C1Q		C1Q
(6) Cement Bond Log		*		C3Q	C3Q	C3Q	C3Q		C3Q		C3Q	*		C3Q
(7) Perforated Depth Control							C3Q				C3Q			
(8) Casing Collar Log and Perforating Record														
(9) Oriented Perforating Record and Casing Collar Log				C3Q	C3Q	C3Q	C3Q		C3Q		C3Q			C3Q
b. Geophysical Logs, Other														
(1) Welex, Micro-seismogram		C1Q										C1Q		
(2) McCullough, Temperature				C1Q										
8. Field Lithologic Log	C1Q	C3Q	C1Q	C1Q	C1Q	C1Q	C3Q	C2Q	C3Q	C3Q	C3Q	C3Q	C1Q	C3Q
9. Cored Interval (feet from surface)														
a. Top	NA	1270	NA	NA	NA	NA	550	NA	1195	580	1200	1200	NA	750
b. Bottom	NA	1519	NA	NA	NA	NA	2525	NA	2220	2608	2750	2211	NA	2810
10. Assay Data														
a. Fischer Assay	NA	C1Q	NA	NA	NA	NA	C3Q	NA	C3Q	C3Q	C2Q	C1Q	NA	C3Q
b. Soluble Sodium	NA	C1Q	NA	NA	NA	NA	C3Q	NA	C3Q	C3Q	C2Q	C1Q	NA	C3Q
c. Alumina	NA	C1Q	NA	NA	NA	NA	C3Q	NA	C3Q	C3Q	C2Q	C1Q	NA	C3Q
11. Trace Element Analysis			C2Q 3Q							C2Q 3Q	C2Q 3Q	C2Q 3Q		
12. Rock Mechanics Data		C1Q										C1Q		
13. Gas Data														
a. Drilling Log	NA	NA	NA	NA		NA	C1Q		C1Q	C1Q	C1Q		NA	C1Q
b. Bomb Samples (# taken)	NA	NA	NA	NA	2	NA	8		4	11	8		NA	6
c. Bomb Analyses	C3Q	NA	NA	NA	C2Q	NA	C1Q 2Q		C1Q	C1Q 2Q	C1Q			C3Q C1Q
14. Completion Data	C2Q	C1Q	C1Q	C1Q	C1Q	C1Q	C3Q	C2Q	C1Q	C2Q	C1Q	C1Q	C1Q	C1Q
15. Survey Plat	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C3Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q

KEY: NA = Not Applicable
Inc. = Incomplete
C1Q = Complete, First Quarterly Report
C2Q = Complete, Second Quarterly Report
C3Q = Complete, Third Quarterly Report

AT = Aquifer Test
CH = Core Hole
GHT = Groundwater Test Hole

*Birdwell Company logs run on this well instead of Schlumberger. See Quarterly Report #1.
**Alluvial Pump Test.
\# Not applicable. Wells drilled prior to granting C-b Tract Lease.

TABLE II-1 (continued)
WELL SUMMARY TABLE

1. Well Designation	SG-17	SG-18	SG-18a	SG-19	SG-20	SG-21	Cb-1	Cb-2	Cb-2b	Cb-3	Cb-4	NQ7B	NQ12D	NO 4	NQ22
2. Well Type	CH	AB (GHT)	GHT	CH GHT	GHT	GHT	GHT	GHT	AB (GHT)	GHT	GHT	CH	CH	CH	CH
3. Completion Date	1/13/ 75	10/13/ 74	10/18/ 74	9/28 74	12/13/ 74	1/8/ 75	#	#	9/20/ 74	#	#				
4. Total Depth (Geolograph)	2460	1430	1330	980	987	1036	2104	1482	1220	2122	1470	1740	1670	1554	1841
5. Water Data							#	#		#	#	---	-None-	-----	-----
a. Drilling Water Production	C2Q	C1Q	C1Q	C1Q	C2Q	C2Q			C1Q						
b. Drilling Water Samples	31	3	1	4	5	5									
c. Water Quality Analyses	C2Q 3Q	C1Q	C1Q	C1Q	C2Q	C2Q									
6. Aquifer Data							#	#		#	#	-----	None	-----	---
a. Drill Stem Tests	C2Q 3Q				C2Q 3Q	C2Q 3Q									
b. Jetting Tests	C2Q 3Q	C1Q	C1Q	C1Q	C2Q	C2Q									
7. Geophysical Logs,															
a. Schlumberger (1) Borehole, Compensated Sonic	C2Q	C1Q		C1Q	C2Q	C2Q						*		*	*
(2) Laterolog	C2Q	C1Q		C1Q		C2Q						*	*	*	*
(3) Formation Density	C2Q	C1Q		C1Q	C2Q	C2Q						*	*	*	*
(4) Compensated Neutron Formation Density												*	*	*	*
(5) Temperature	C2Q	C1Q		C1Q	C2Q	C2Q	C2Q	C2Q		C2Q	C2Q	*	*	*	*
(6) Cement Bond Log	C3Q						C3Q	C3Q			C3Q				
(7) Perforated Depth Control	C3Q						C3Q	C3Q							
(8) Casing Collar Log and Perforating Record							C3Q	C3Q			C3Q				
(9) Oriented Perforating Record and Casing Collar Log	C3Q														
b. Geophysical Logs, Other															
(1) Birdwell, Caliper log												*	*	*	*
(2) McCullough, Temperature															
8. Field Lithologic Log	C3Q	C3Q	C1Q	C3Q	C2Q	C2Q	#	#	C1Q	#	#				
9. Cored Interval							#	#		#	#				
a. Top	800	1380	NA	930					NA			70	70	70	70
b. Bottom	2460	1426	NA	980								TD	TD	TD	TD
10. Assay Data							#	#	NA	#	#				
a. Fischer Assay	C3Q	C3Q		C1Q	C3Q	C3Q									
b. Soluble Sodium	C3Q	C3Q		C3Q	C3Q	C3Q									
c. Alumina	C3Q	C3Q		C3Q	C3Q	C3Q									
11. Trace Element Analysis							#	#	NA	#	#				
12. Rock Mechanics Data							#	#	NA	#	#				
13. Gas Data							#	#		#	#				
a. Drilling Log	C2Q	C1Q	C1Q	C1Q	C2Q				C1Q						
b. Bomb Samples	31	1	1	4	5	4			1			5	4	4	4
c. Bomb Analyses	C1Q-C3Q	C1Q	C1Q	C1Q	C2Q	C2Q			C1Q			C4Q	C4Q	C4Q	C4Q
14. Completion Data	C2Q	C1Q	C1Q	C1Q	C2Q	C2Q	C1Q	C2Q	C1Q	C1Q	C1Q	C4Q	C4Q	C4Q	C4Q
15. Survey Plat	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C1Q	C3Q	C3Q	C4Q	C4Q

KEY: NA = Not Applicable
Inc. = Incomplete
C1Q = Complete, First Quarterly Report
C2Q = Complete, Second Quarterly Report
C3Q = Complete, Third Quarterly Report

AT = Aquifer Test
CH = Core Hole
GHT = Groundwater Test Hole

*Birdwell Company logs run on this well instead of Schlumberger. Logs in Quarterly Report #4.
**Alluvial Pump Test.
Not applicable. Wells drilled prior to granting C-b Tract Lease.

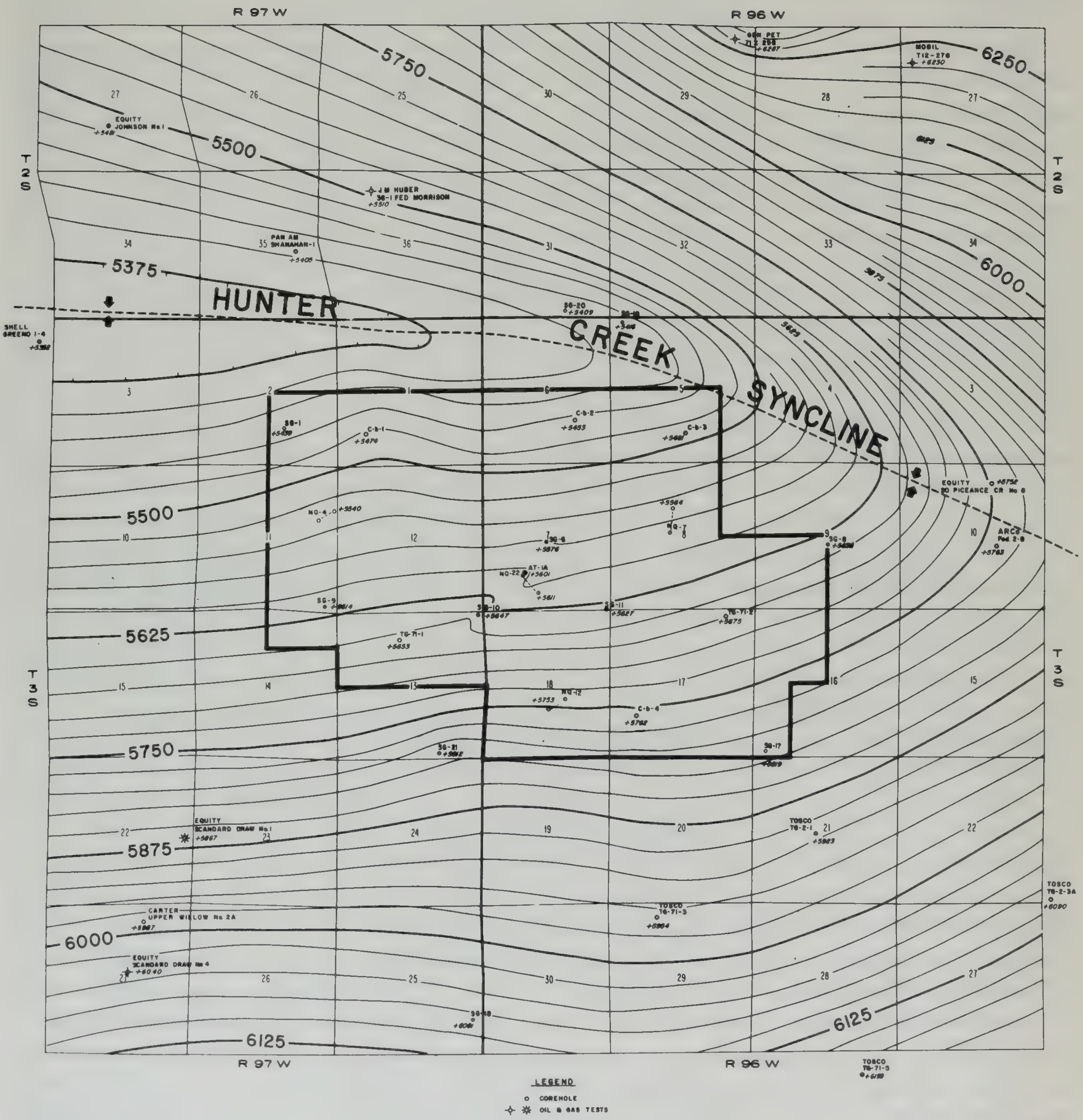


Figure II-4 **STRUCTURE CONTOUR TOP MAHOGANY ZONE**
TRACT C-b

Detailed surface mapping of the Tract and surrounding area has not disclosed any significant faults. The nearest significant faults occur on the Sulphur Creek Anticline about two miles northwest of the Tract. Faults also are present on the Piceance Creek Anticline approximately three miles north of the Tract.

Fractures or joints are abundantly evident in the outcrops of the Uinta Formation sandstones and siltstones on and around Tract C-b. Joint sets have been measured at 39 locations which are fairly evenly distributed over the Tract. These data have been analyzed to identify trends by constructing a stereographic net contour diagram (Figure II-5). The higher percentage areas on the diagram define two dominant joint sets. One joint set strikes N 72° W and dips vertically. The other strikes N 75° W and dips 66° to the north. Significant fracture trends in other directions are not apparent.

Fractures are also abundant in cores of the Parachute Creek oil shale. Studies of the rock quality of the shales suggest the rich oil shales are less intensely fractured than the lean oil shales. This concept is supported by pump tests in the SG-1 and SG-1a core holes which determined that the vertical permeability of a zone of thin, rich oil shale is less than 0.1 millidarcies.

Structural and topographic information has been used to prepare an overburden map of the Tract area. Figure II-6 shows the thickness of the overburden to the top of the anticipated mine roof. Overburden thickness ranges from less than 1000 feet along the major drainage to more than 1300 feet along the ridge crests. Because both the land surface and the beds slope to the north at about the same rate, changes in overburden thickness mostly reflect local variations in topographic relief.

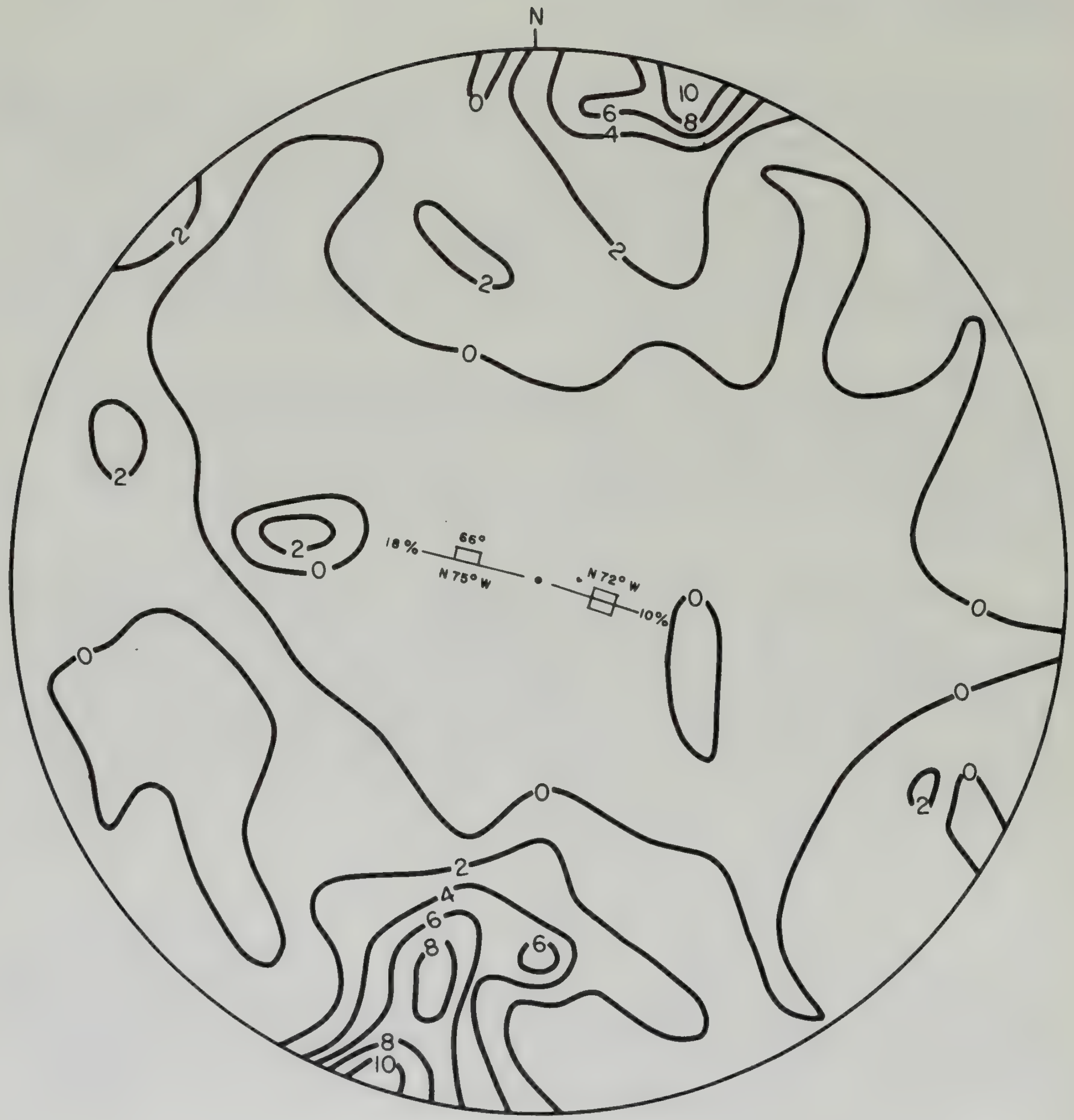
C. Stratigraphy

1. Green River Formation

The Green River Formation which contains the oil shale deposits of interest, conformably overlies the Wasatch Formation and is divided into three members listed in stratigraphically ascending order as follows: Douglas Creek, Garden Gulch and Parachute Creek. Only the Parachute Creek member would be involved in oil shale development on Tract C-b.

The Parachute Creek member is composed almost entirely of organic marlstones (oil shale) of varying richness. The unit averages about 1600 feet in thickness beneath the Tract. As shown in Figure II-7 the Parachute Creek member has been subdivided into a number of units based on richness differences and other physical properties.

The Mahogany zone is the unit of principal interest beneath the Tract because it contains the richest oil shale section in this part of the basin. It range from 174 to 187 feet in thickness. The Mahogany zone is bounded at the top by a lean oil shale unit about 15 feet in thickness known as "A" Groove and is bounded at the base by a lean oil shale unit 20 feet in thickness called "B" Groove.



Data from 39 locations on Tract C-b plotted on lower hemisphere. Contours indicate percent of all joint poles that lie within an area equal to one percent of total area of diagram.

Figure II-5 STEREOGRAPHIC NET CONTOUR DIAGRAM OF JOINT MEASUREMENTS

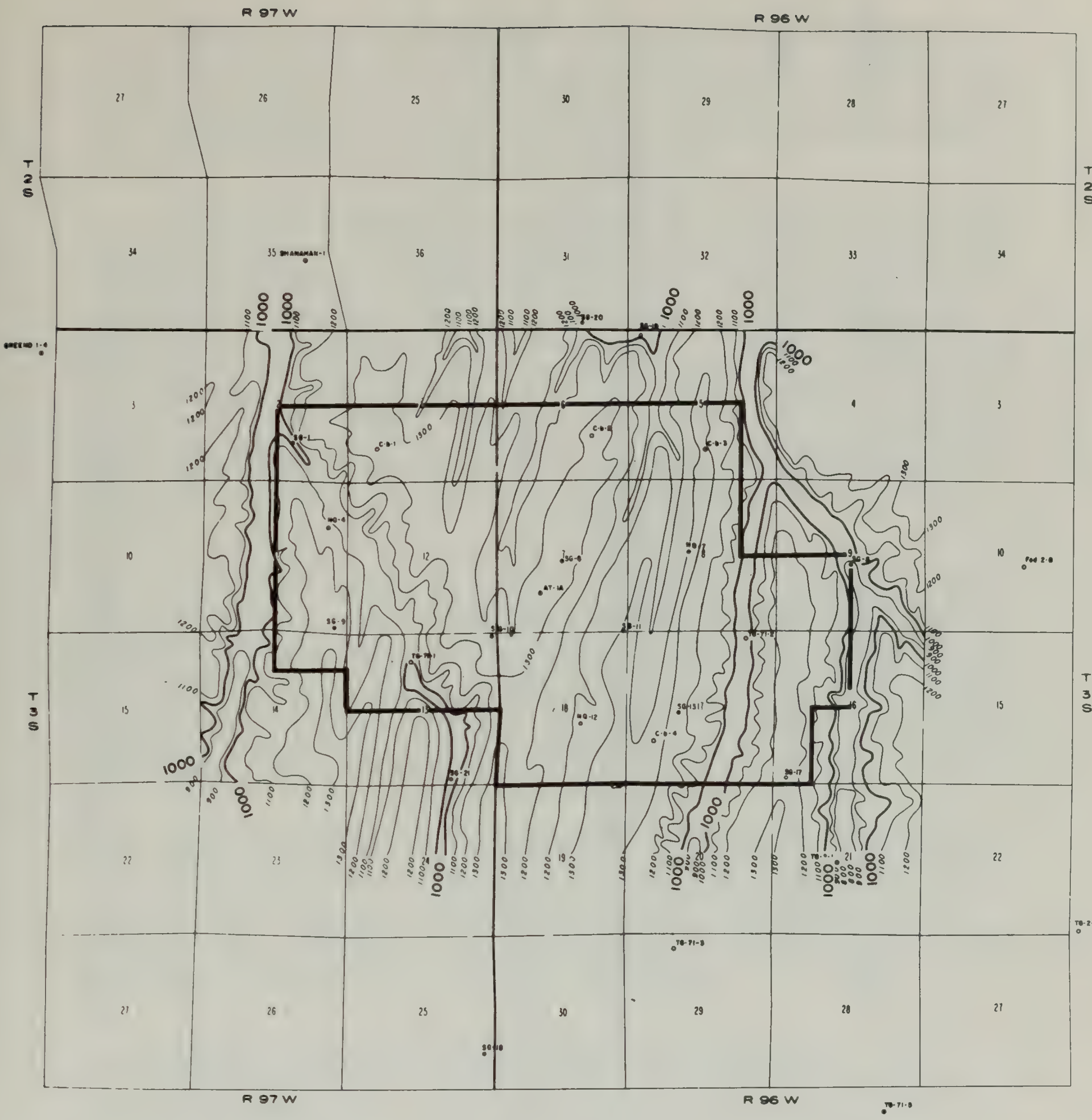


Figure II-6 **PRELIMINARY ISOPACH OF OVERBURDEN SURFACE TO MINE ROOF TRACT C-b**

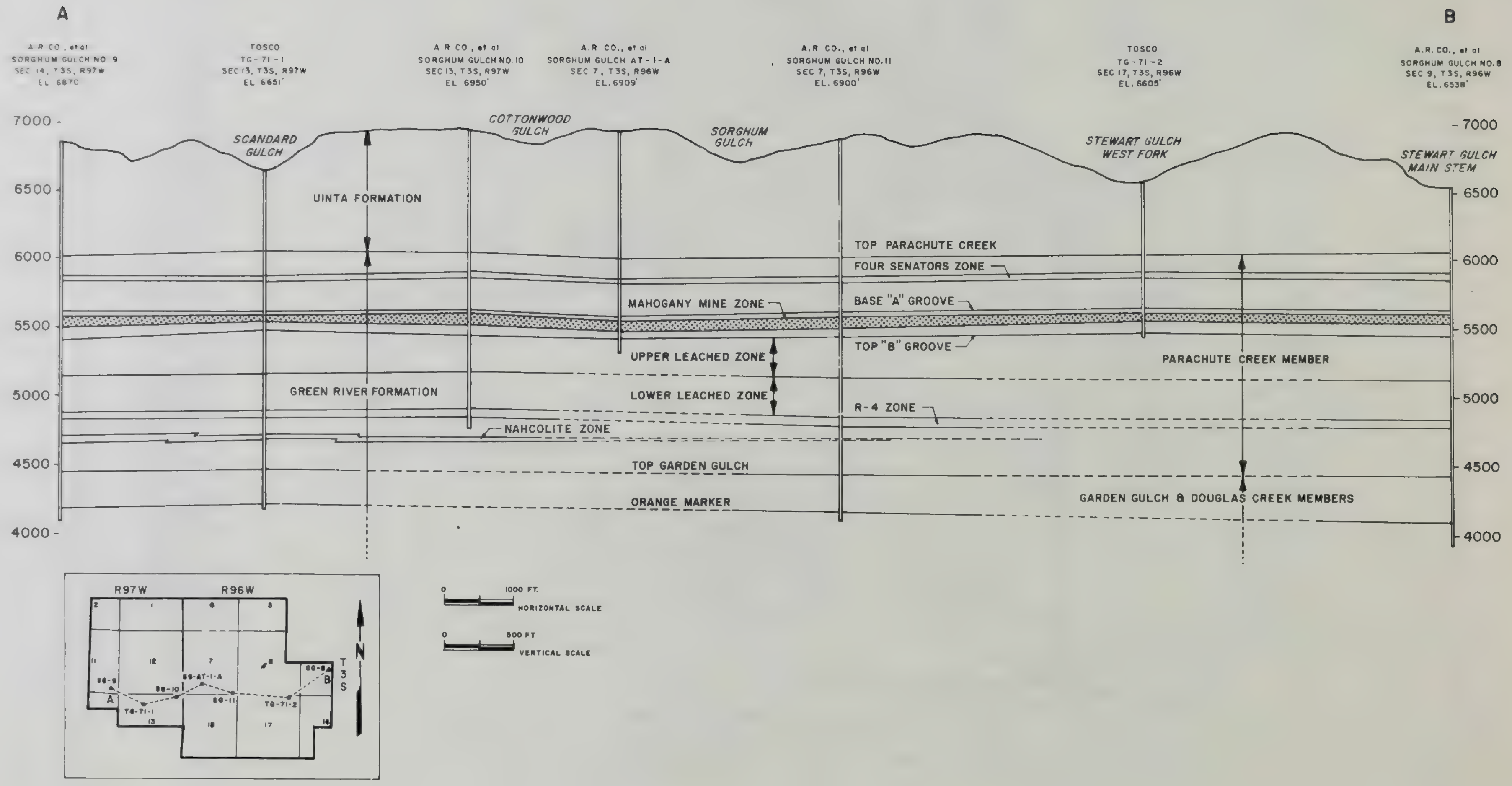


Figure II-7 EAST-WEST STRATIGRAPHIC CROSS SECTION TRACT C-b

The mine zone of primary interest at this time is an interval of rich oil shale within the Mahogany zone with an average thickness of 77 feet. The top of this interval is generally encountered about 35 feet below the base of "A" Groove and ranges in thickness from 74 to 83 feet. For planning purposes the preferred mining interval has been divided into three subdivisions as shown in Figure II-8.

The oil shale section between the base of "B" Groove and the base of the Parachute Creek member is customarily referred to as the "lower oil shale zone." In the north-central part of the basin this interval is comprised almost entirely of rich oil shale. However, the Tract is peripheral to the basin depocenter and the lower oil shales here are much leaner in comparison to the basin center. Figure II-8, which is an example log for the Tract, shows the distribution of oil shale richness in the "lower oil shale zone." In general these oil shale zones are too lean and too intensely fractured to be mined. The R-4 zone appears to be the only interval in the "lower oil shale zone" beneath the Tract with adequate grade and rock quality to have some future commercial potential. However, present plans do not include the mining of this zone.

The maximum in-place shale oil resource for Tract C-b is currently estimated to be 1.52 billion barrels of oil which is the total of the 77-foot mine zone within the Mahogany zone and the 55-foot R-4 zone below the Mahogany zone. In the "Final Environmental Statement For the Prototype Oil Shale Leasing Program," the Federal Government estimated that the total shale oil resource is 723 million barrels of oil. The government's figure is based on a conceptual plan to mine a 50-foot unit within the Mahogany zone and a 50-foot unit below the Mahogany zone. Both units are assumed to average 30 gallons of oil per ton.

Both nahcolite ($NaHCO_3$) and dawsonite ($NaAl(OH)_2CO_3$) are present in the Parachute Creek member. Nahcolite is occasionally found in nodule form within the Mahogany zone but in such small amounts that it affords no apparent commercial potential. Dawsonite is found throughout the Mahogany zone. However, as the concentration of potentially recoverable alumina (Al_2O_3) in this part of the section averages less than 1 percent, dawsonite extraction is not economically feasible.

Samples of the Parachute Creek member from four core holes have been analyzed to determine concentrations of antimony (Sb), arsenic (As), boron (B), cadmium (Cd), fluorine (F), mercury (Hg) and selenium (Se). Except for the concentrations of fluorine and arsenic, which gradually increase with depth, no strong correlations between concentrations of elements and depth or stratigraphic zone are indicated. The range of concentrations of these trace elements is as follows (the mean is based on 141 samples):

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THE OIL SHALE CORPORATION

TG 71-1 COREHOLE
SEC. 13-TS3-R97W
RIO BLANCO COUNTY, COLORADO
T.D.–2530'
EL. 6651' G.L.

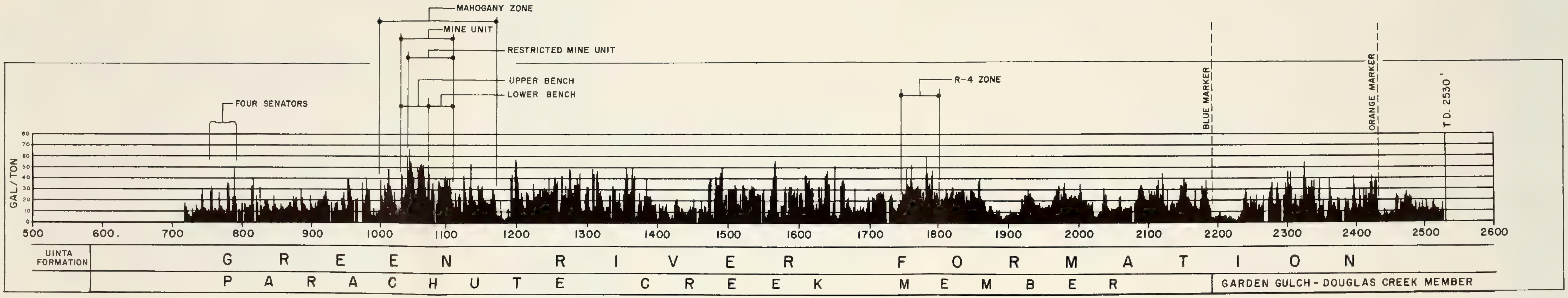

Figure II-8 TYPICAL RICHNESS HISTOGRAM FOR TRACT C-b

Element	Concentration (PPM) Maximum	Mean	Minimum
Antimony	3.0	--	<1.0
Arsenic	125.0	45.9	10.0
Boron	300.0	47.5	10.0
Cadmium	0.7	--	<0.5
Fluorine	3400.0	--	600.0
Mercury	1.3	0.264	0.02
Selenium	10.0	--	<2.0

The only two trace elements in the oil shale that also occur in significant amounts in the ground water are fluorine and boron. Fluorine may reach a concentration of 45 PPM in highly saline water below the R-4 zone but normally does not exceed 20 PPM. Boron concentration in ground water may be as high as 47 PPM in saline water but is usually less than 3 PPM. None of the trace elements occurs in significant amounts in the surface waters of the basin, except fluorine, which is present in low concentrations.

2. Uinta Formation

The Uinta Formation overlies the Parachute Creek member of the Green River Formation and comprises the surface bedrock over Tract C-b. The Uinta Formation consists mostly of light-brown and gray, silty sandstone, and tan-to-gray carbonaceous siltstone, with lesser amounts of marlstone and shale. In general the marlstones are barren or contain only small amounts of organic material. Throughout the Uinta Formation there is much lateral variability in lithology and, except for some of the thicker marlstone units, most beds cannot be correlated over any significant distance. The Uinta Formation ranges from about 400 feet to 900 feet in thickness across the Tract. Figure II-9 is a surface geologic map showing several local mappable units in the Uinta Formation that have been indentified on the Tract.

3. Recent Deposits

Recent deposits on the Tract include flood plain alluvium, fan alluvium, colluvium and mixed alluvium-colluvium. Floodplain alluvium forms the flat-bottomed floors of Piceance, Hunter and Willow Creeks and Stewart Gulch and is found to some extent up Scandard Gulch. Fan alluvium occurs where tributaries enter the larger valleys. The number of fans is large but the individual areal extent is quite small. Colluvium occurs on the uplands and at the base of valley walls between alluvial fans. The alluvium-colluvium deposits cover areas where the depositional agent is unknown. Thick accumulations of alluvium-colluvium can be found in upland areas. Where they occur in the upper reaches of the draws or on steep slopes, they are unstable particularly to the passage of large amounts of water. The distribution of these units is shown on Figure II-9.

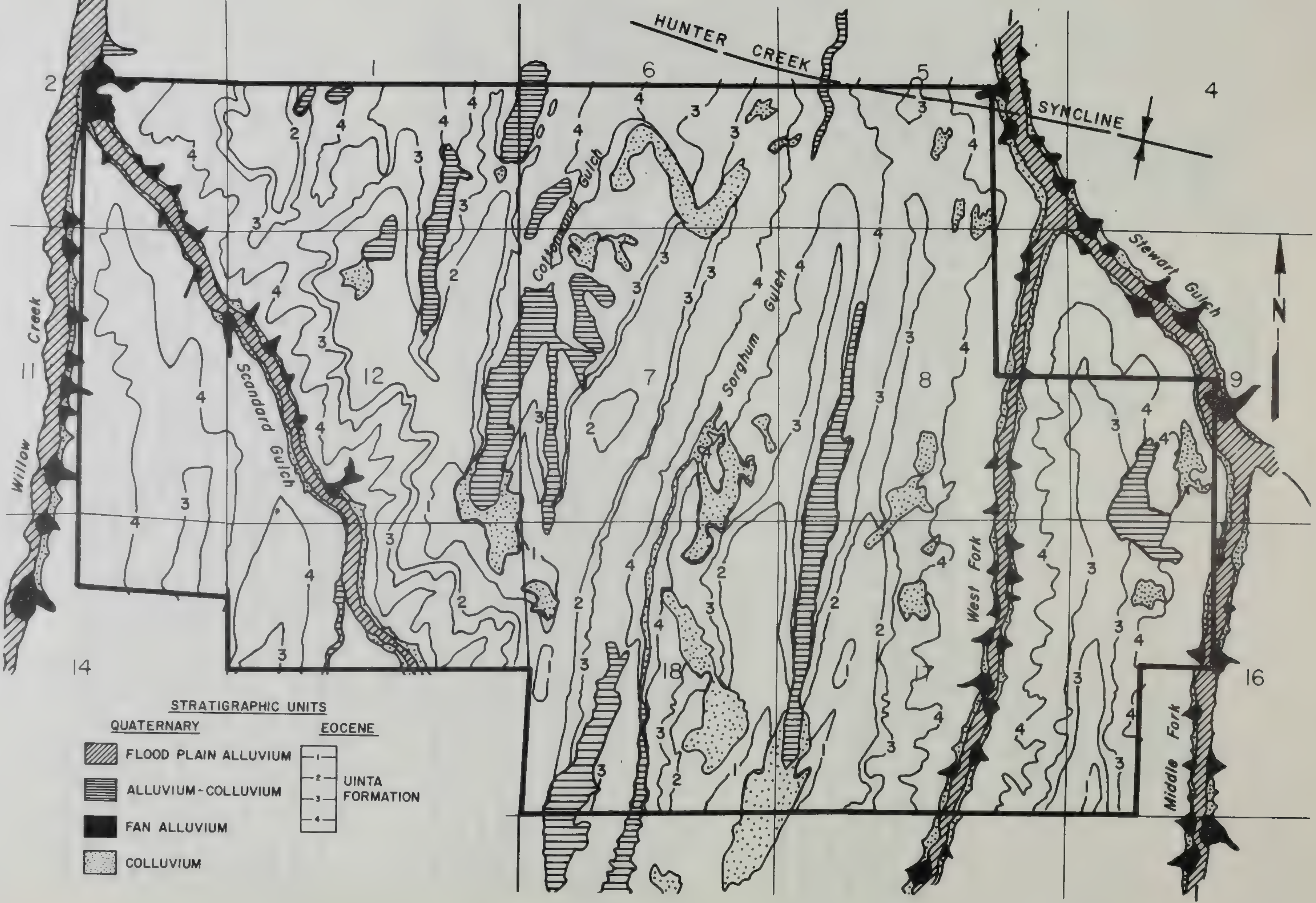

Figure II-9 **SURFACE GEOLOGIC MAP**
TRACT C-b AND VICINITY

D. Geologic Hazards

Detailed surface geologic mapping of the Tract and vicinity was conducted to identify existing natural hazards such as landslides, rockfall areas, slump fractures, soil creep and mud flow areas. Minor soil creep and slump occurs near the heads of several tributaries along Willow Creek. Based on generalized evaluations by the Earthquake Tectonics Branch, United States Geological Survey, Tract C-b is within the lowest seismic risk zone.

Areas of Quaternary deposits, which include floodplain alluvium, fan alluvium, colluvium and mixed alluvium and colluvium, have the greatest potential for erosion. The areas are shown on Figure II-9.

At present erosion appears to be most severe at the heads of some of the smaller gulches. The alluvial material is locally incised 20 to 30 feet below the floors of the gulches and the heads of the gulches exhibit slopes on the order of 45^{o}.

Significant flooding will generally be restricted to established stream floodplains which are defined by the distribution of floodplain alluvium. Sheet flooding will occur essentially everywhere.

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III. HYDROLOGY AND WATER QUALITY

A. Program Description

The Environmental Stipulations attached to the C-b Lease establish a number of requirements for monitoring both surface and subsurface waters on and near the Tract. The objectives of these requirements are: 1) to establish baseline values for the quantity and quality of all water resources associated with the Tract and 2) to provide a means for monitoring any future changes in these resources owing to the development of a shale oil extraction plant.

In addition to satisfying the above direct requirements of the lease, the hydrology program has been designed to obtain information needed to estimate the problems of water inflow to the access shaft and mine, to determine the need for importation of surface water and to evaluate methods for disposing of excess water if necessary.

Terms of the Stipulations require that surface water gauging stations be located on the major drainages of the Tract and, as defined by the AOSS, upstream and downstream of the leased lands. Records are kept of stream flow, water temperature, precipitation and sediment; periodic analyses are made for selected chemical constituents. The stations were constructed through a contract arrangement with the United States Geological Survey and the Colorado River Water Conservation District. The USGS Water Resources Division sub-district office in Meeker, Colorado is responsible for operation and maintenance of the stations through the same contract arrangement.

In accordance with the terms of the lease an inventory of natural surface features, such as seeps and springs, was conducted by field geologists. No significant seeps or springs have been found on the Tract. However, a number of nearby springs have been sampled. Flow records for some of these springs are available from the Colorado Division of Water Resources.

With respect to ground water measurements the lease requires:

1. A pumping test well at any proposed mine site.

2. An observation well in the mine zone and any aquifer above and below the mine zone.

3. An observation well upgradient from any proposed spent shale disposal site.

4. At least two observation wells down gradient from any proposed spent shale disposal site.

Aquifer characteristics such as transmissivity, storage coefficient, potentiometric surface, water quality, discharge and recharge rates are sought to aid in the development of a mining plan and to predict local and regional effects which may develop due to groundwater withdrawal. In general the hydrology program has involved jetting tests, pumping tests, drill-stem tests, water-quality sampling and water-level measurements. One or more of these tests was run on 34 wells drilled during the year.

An on-going program of recording water levels and periodic sampling for chemical analysis has been established using several core holes which existed prior to the leasing of the Tract as well as new core holes, aquifer test wells and alluvial observation wells.

B. Streams

1. Monitoring Stations

Figure IIA-1 (5th Quarterly Summary Report) shows the approximate locations and official USGS serial number designations of the 13 stream-gauging stations which have been installed on or near the Tract. Data collection for the surface water program began on April 19, 1974.

Table III-1 summarizes the instrumentation and data obtained at each location. Table III-2 lists the chemical analyses performed and the sampling frequency for the first year of baseline data. Nine of the stations are located on ephemeral or intermittent streams. The other four, however, are located on perennial drainages and are considered major gauging stations.

2. Flow Records

Stream flow from the Piceance Creek drainage basin is typical of those regions where the primary source of stream flow is snowmelt. Precipitation for the months of November through March is stored in the snowpack at the higher altitudes of the basin and becomes available for recharge and runoff as daily temperatures and solar radiation increase in the Spring. Snowmelt produces a period of high stream flow starting in March or April and continuing through June or July. Stream flow for the remainder of the year is maintained almost totally by ground water discharge, which moves through the alluvium into the stream channels or appears as springs along the valley floors. Evapotranspiration rates are high during the summer and most of the precipitation that occurs during this period is evapotranspirated. Only high-intensity thunderstorms, which are usually limited to a small area, produce any significant contributions to summer streamflow.

Hydrographs for the four major gauging stations are presented in Figures III-1, III-2, III-3 and III-4. These represent points on Piceance Creek upstream and downstream of the Tract (Stations 007 and

Table III-1 SURFACE WATER GAUGING STATIONS INSTRUMENTATION

	U.S.G.S. STATION NO.	U.S.G.S. STATION DESCRIPTION	Streamflow Recorders	Sediment Samplers	Temperature & Specific Conductivity Recorders	4-Parameter Recorders (+)	Turbidity Recorders
(*)	09306007	Piceance Creek below Rio Blanco	x	x		x	x
	09306015	Middle Fork Stewart Gulch nr Rio Blanco	x	x	x		x
	09306022	Stewart Gulch at West Fork nr Rio Blanco	x	x		x	
	09306025	West Fork Stewart Gulch nr Rio Blanco	x	x	x		
	09306028	West Fork Stewart Gulch at mouth near Rio Blanco	x	x	x		
	09306033	Sorghum Gulch nr Rio Blanco	x	x	x		
	09306036	Sorghum Gulch at mouth nr Rio Blanco	x	x	x		
	09306039	Cottonwood Gulch nr Rio Blanco	x	x	x		
	09306042	Piceance Creek Tributary nr Rio Blanco	x	x	x		
	09306050	Scandard Gulch nr Rio Blanco	x	x	x		
	09306052	Scandard Gulch at mouth nr Rio Blanco	x	x	x		
(*)	09306058	Willow Creek nr Rio Blanco	x	x		x	
(*)	09306061	Piceance Creek at Hunter Creek nr Rio Blanco	x	x		x	x

(*) – Major Gauging Station

(+) – Includes pH, Dissolved Oxygen, Temperature, and Specific Conductivity

Storage-type rain gauges are installed at Stations 09306015, 09306022, 09306050, and 09306058. In addition, precipitation data is being recorded at five air quality stations on or near the Tract.

Table III-2 SURFACE WATER QUALITY ANALYTICAL PROGRAM REQUIREMENTS

	Semi-Monthly	Quarterly	Continuous	Continuous When Possible
1. Ammonia	x			
2. Aromatics, Polycyclic		x(M)		
3. Arsenic	x			
4. Barium	x			
5. Bicarbonate	x			
6. Boron	x			
7. Cadmium	x			
8. Calcium	x			
9. Carbonate	x			
10. Chloride	x			
11. Chromium	x			
12. COD		x(M)		
13. Coliform, Total & Fecal		x(M)		
14. Color	x			
15. Conductivity, Specific			x(M)	x(0)
16. Copper	x			
17. Cyanide	x			
18. Dissolved Oxygen	x		x(M)	
19. Fluoride	x			
20. Gross Alpha*		x(M)		
21. Gross Beta*		x(M)		
22. Iron	x			
23. Kjeldahl Nitrogen	x			
24. Lead	x			
25. Lithium	x			
26. Magnesium	x			
27. Manganese	x			
28. Mercury	x			
29. Nitrate	x			
30. Nitrite	x			
31. Odor	x			
32. Oil & Grease	x			
33. Ortho-Phosphate	x			
34. Pesticides		x(M)		
35. pH	x	x(M)		
36. Potassium	x			
37. Selenium	x			
38. Silica	x			
39. Sodium	x			
40. Solids, Dissolved	x			
41. Solids, Suspended (sediment)			x(M)	x(0)
42. Sulfate	x			
43. Sulfide	x			
44. Turbidity	x		x(PC)	
45. Zinc		x(M)		
46. Complete element scan for all trace elements		x(M)		
47. Total Organic Carbon (TOC) If TOC > 10 mg/liter, then Dissolved Organic Carbon Suspended Organic Carbon Phenols Sulfur (acid extraction) Nitrogen (base extraction)				
48. Stream Flow (discharge)			x(M)	x(0)
49. Water Temperature			x(M)	x(0)

* - Depending on count, thorium 230, radium 226, and natural uranium may be required.
(M) - Major Gauging Stations Only.
(0) - All Gauging Stations Except Major Stations.
(PC) - Piceance Creek Gauging Stations Only.

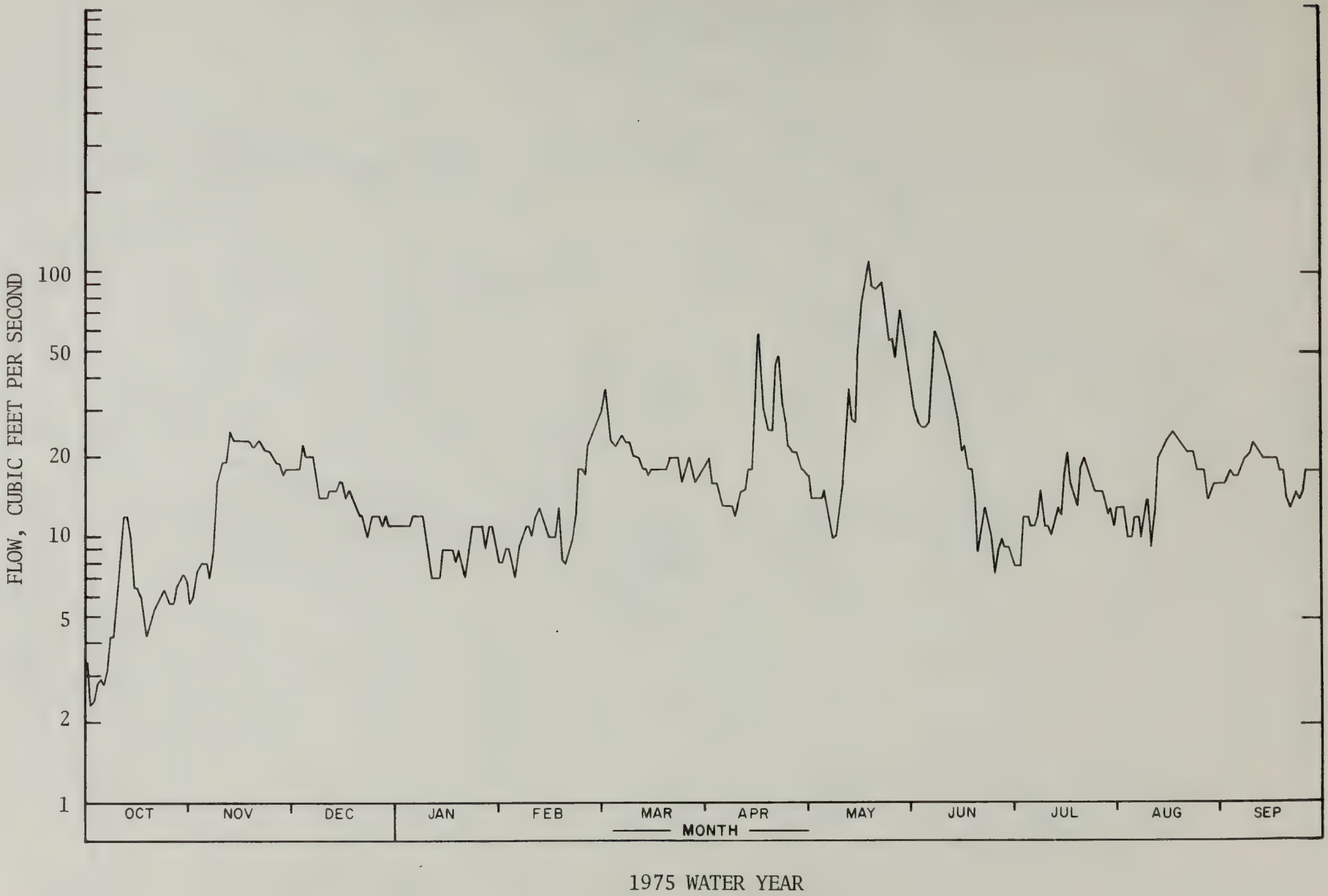
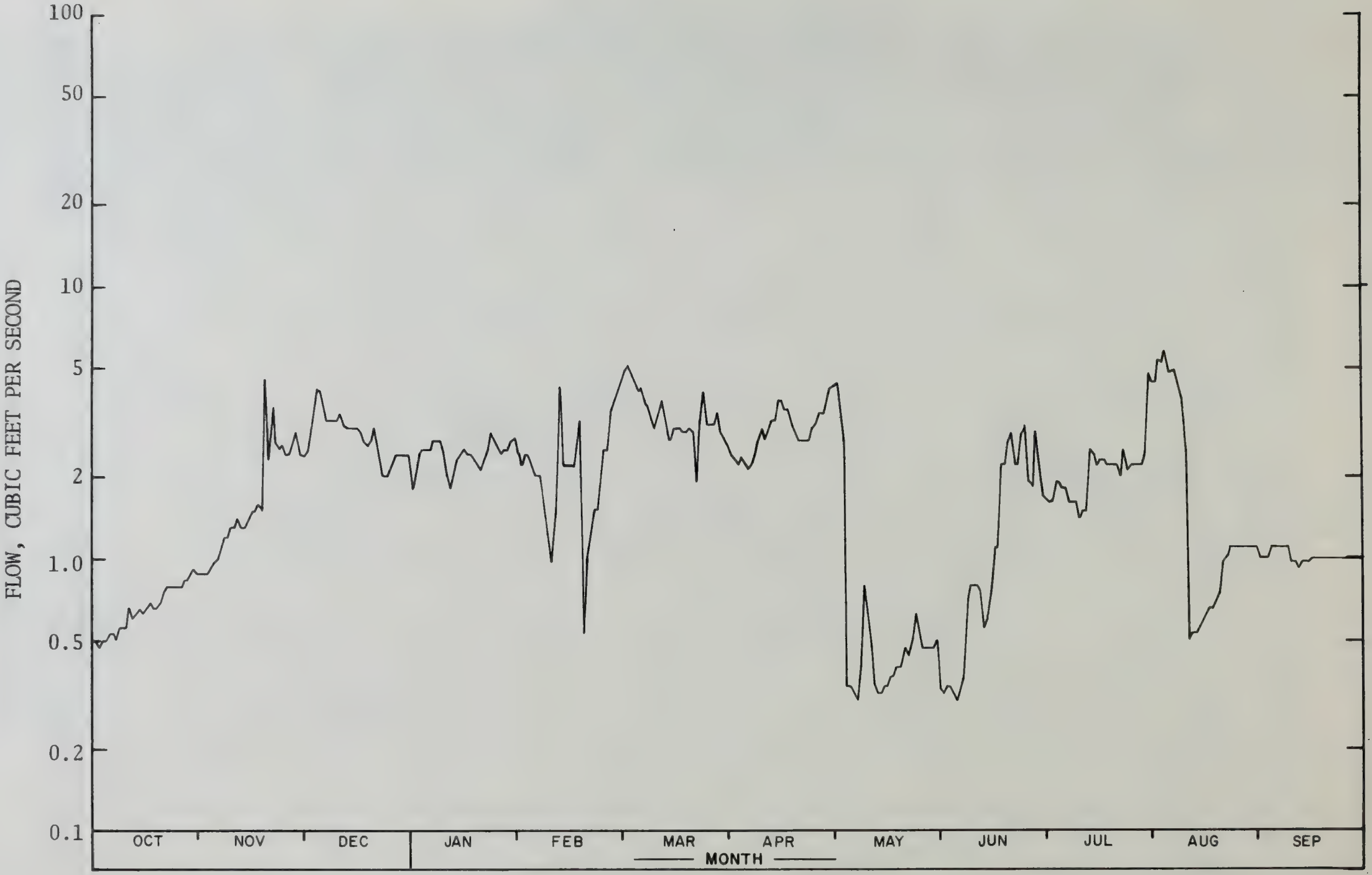


Figure III-1. HYDROGRAPH - PICEANCE CREEK ABOVE HUNTER CREEK NEAR RIO BLANCO (U.S.G.S. #09306061)



1975 WATER YEAR

Figure III-2. HYDROGRAPH - WILLOW CREEK NEAR RIO BLANCO (U.S.G.S. #09306058)

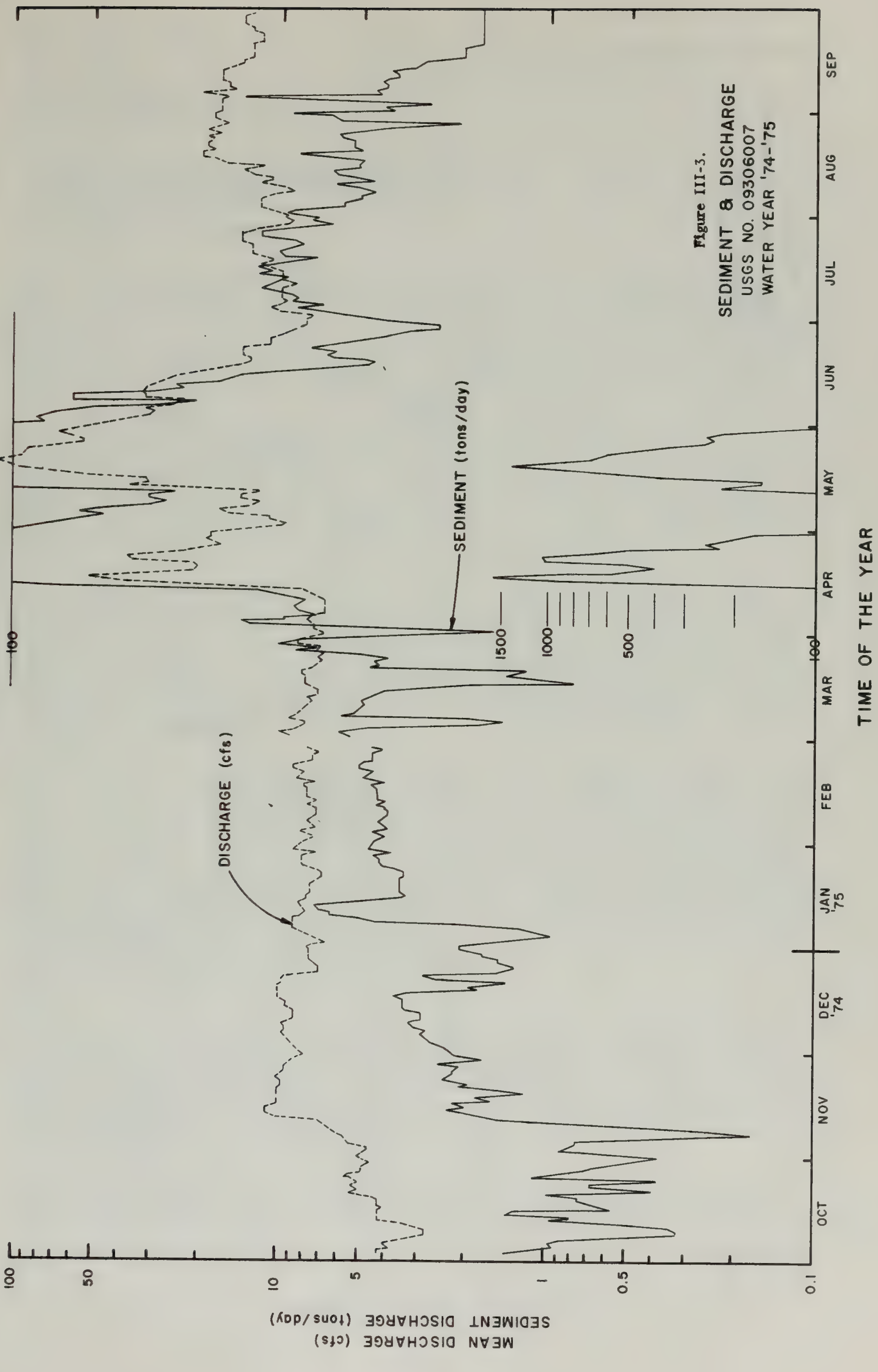
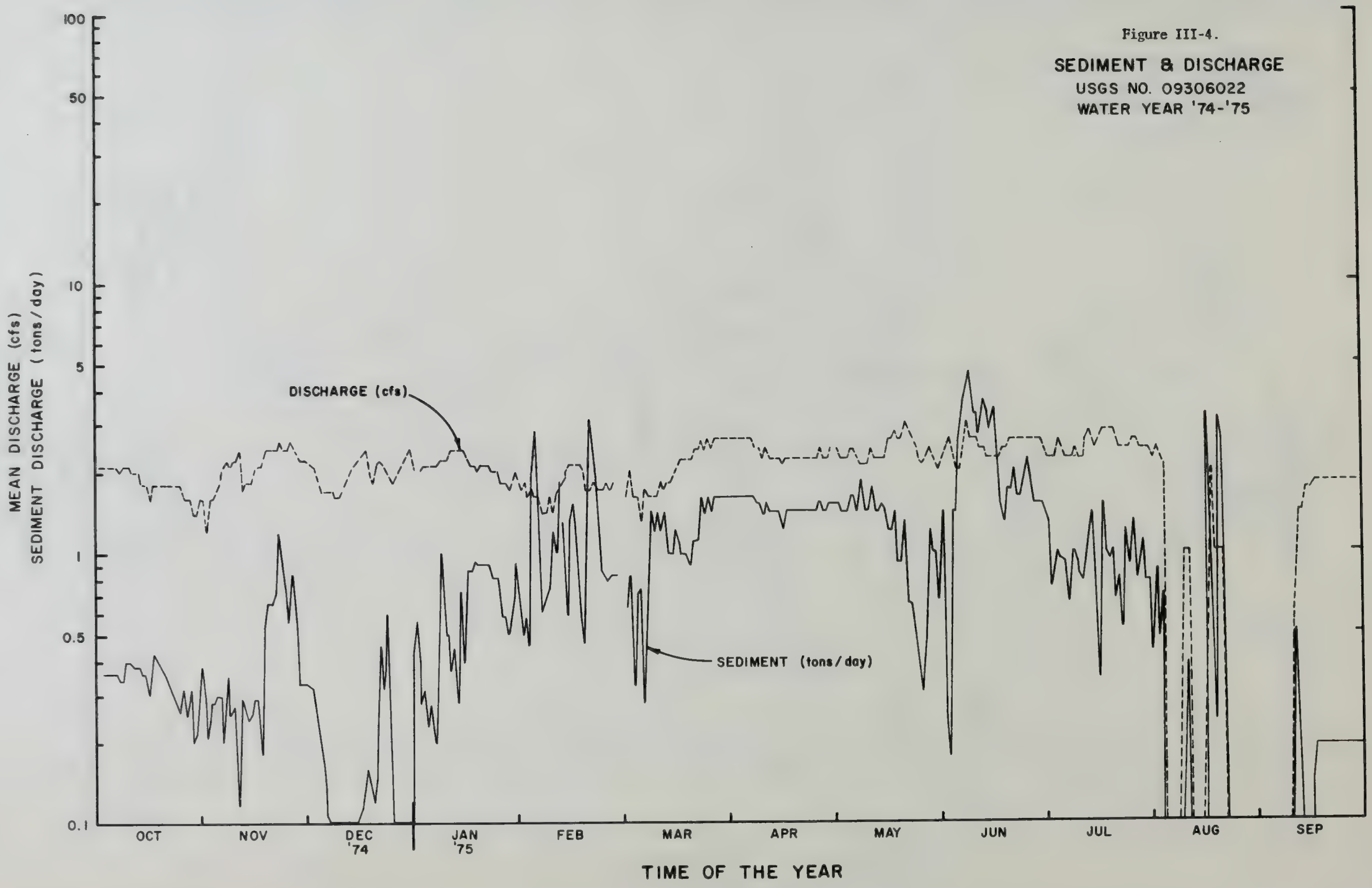


Figure III-3.
SEDIMENT & DISCHARGE
USGS NO. 09306007
WATER YEAR '74-'75

Figure III-4.



SEDIMENT & DISCHARGE
USGS NO. 09306022
WATER YEAR '74-'75
MEAN DISCHARGE (cfs)
SEDIMENT DISCHARGE (tons / day)
100
50
10
5
1
0.5
0.1
DISCHARGE (cfs)
SEDIMENT (tons/day)
OCT
NOV
DEC '74
JAN '75
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
TIME OF THE YEAR

061, respectively) and the two major perennial tributaries bordering the Tract, Stewart Gulch and Willow Creek (Stations 022 and 058, respectively). These data represent the first full Standard Water Year (October 1974 through September 1975) of operation. Most of the stations actually began operation prior to October 1974 and data for that period may be found in Summary Report #1. The only two stations on ephemeral streams which recorded significant flows during the year were West Fork Stewart Gulch, USGS #025 and Cottonwood Gulch, USGS #039 (Figure III-5).

The hydrograph patterns for the Piceance Creek upstream (007) and downstream (061) continuous gauging stations are in general agreement (Figures III-1 and III-3). Flow at the downstream station is greater than the flow at the upstream station (except for isolated peaks which may be attributed to storms) for all months except May. This may be because of water diversion for irrigation during the time period.

The pattern of ephemeral flow exhibited by Station 025 in West Fork Stewart Gulch (Figure III-5) suggests that the flow may be originating from shallow seeps in the alluvium which become frozen during the winter months. Flow observed in Cottonwood Gulch (Figure III-5) is attributed in a large part to the discharge of water from the aquifer test pad during the aquifer pump test program.

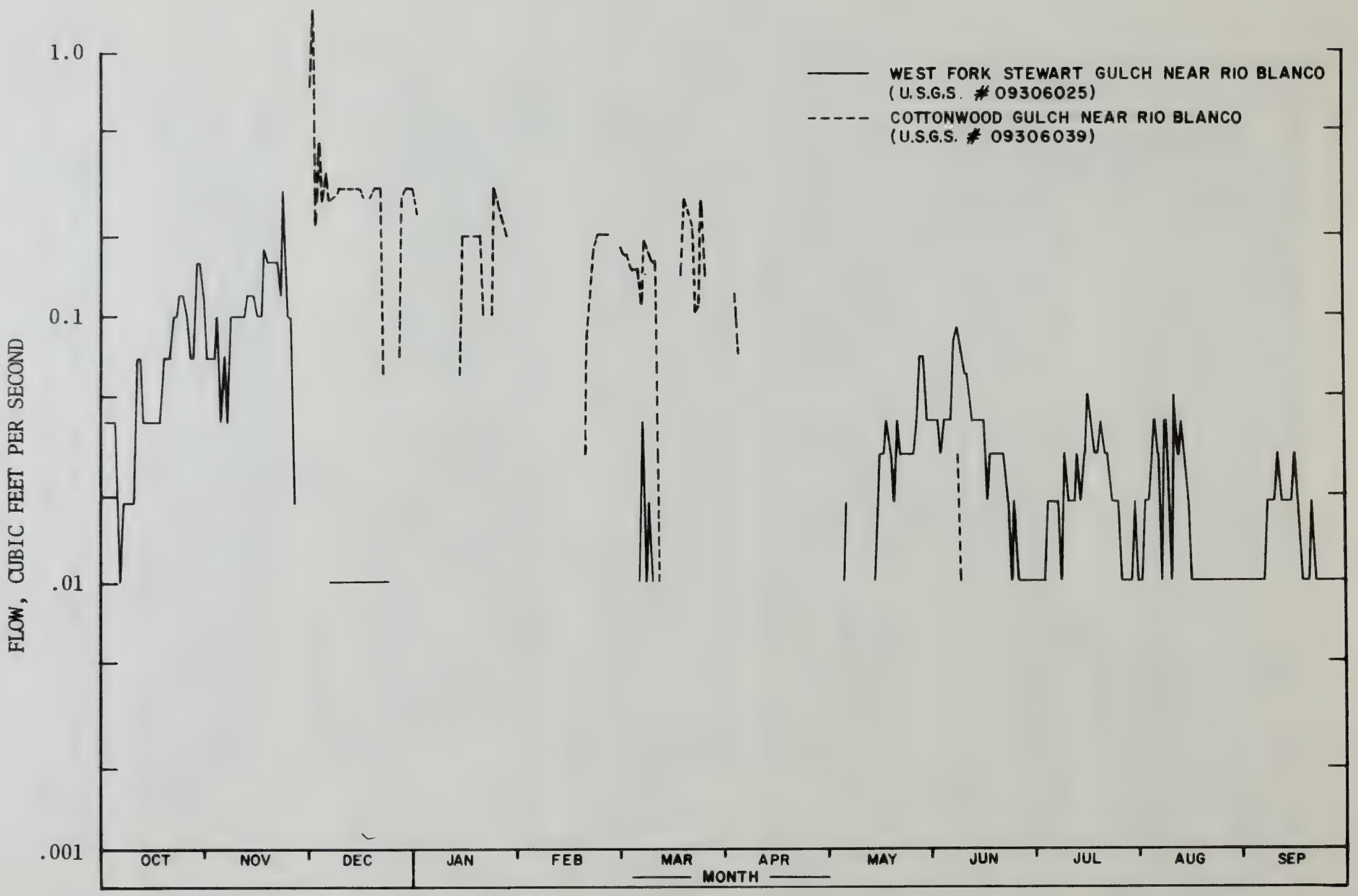
Figure III-3 shows the continuous flow and sediment data for Station 007. For the summer season and particularly the period from June 19 to July 31, more tons per day of sediment passed the upstream recording station than passed the downstream recording station, even though the average flow is greater at the downstream station. These quantities are listed in Table III-3. No obvious explanation for this anomaly is apparent.

Sediment concentrations in the main stem of Piceance Creek (Figure III-6) show much higher increases during the April-May snowmelt-runoff maximum flow period than in the tributaries (Figure III-7). This can perhaps be attributed to the limited drainage area of the tributaries and the proportionately smaller increases in flow and stream velocities. Both flow and sediment records (Figures III-1 through III-7) emphasize the difference between the flow regime of the main stream and that of the tributaries bordering the Tract.

3. Water Quality

A record of surface water quality on and near the Tract is being maintained through the semi-monthly sampling program. Perennial streams are sampled regularly and ephemeral streams during flow events. Data are analyzed by the USGS and presented in the form of computer printouts. Summary tables have been prepared from these printouts and presented in the Quarterly Summary Reports.

Data for the four continuous recording stations, which measure flow, temperature, pH, dissolved oxygen and conductivity, are also



1975 WATER YEAR

Figure III-5. HYDROGRAPH
STATIONS 09306025 And 09306039

Table III-3

FLOW-SEDIMENT RELATIONSHIPS
SUMMER 1975
U.S.G.S. STATIONS 09306061 AND 09306007
PICEANCE Basin

Station	Dates	Days	Average Discharge cfs	Average Sediment Discharge Tons/Day
09306061	June 20-Sept. 30	103	15.4	5.07
09306007	June 19-Sept. 30	104	13.2	6.01
09306061	June 20-July 31	42	12.6	7.2
09306007	June 19-July 31	43	10.9	8.0

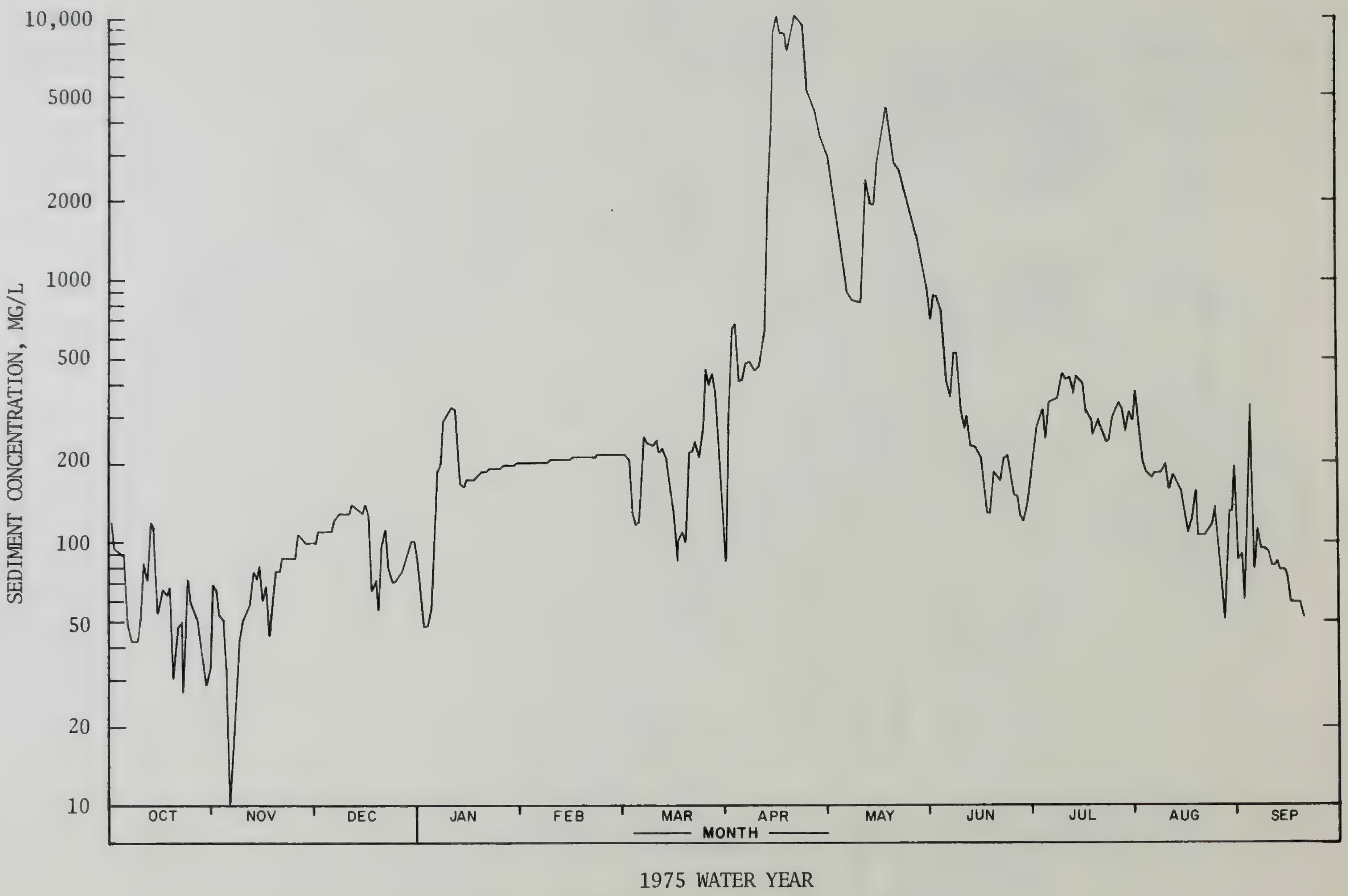


Figure III-6. SEDIMENT CONCENTRATION - PICEANCE CREEK BELOW RIO BLANCO (U.S.G.S. #09306007)

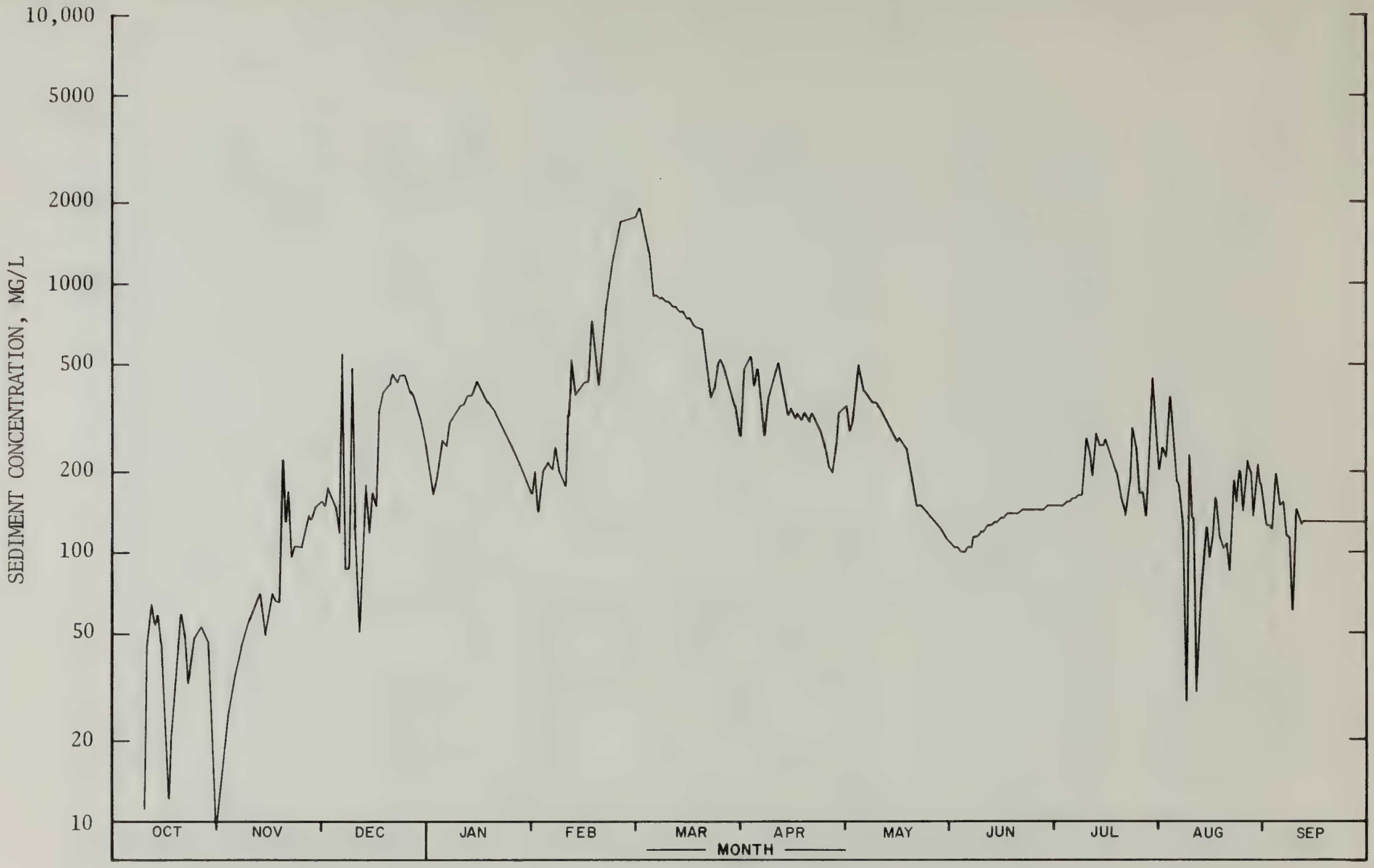


Figure III-7. SEDIMENT CONCENTRATION - WILLOW CREEK NEAR RIO BLANCO (U.S.G.S. #09306058)

available. Sediment concentrations were collected on a daily basis for the four major gauging stations and for a few minor stations. Examples of the continuous monitoring data for dissolved oxygen, temperature, pH, conductivity and turbidity are given in Figures III-8, III-9, III-10, III-11 and III-12. Continuous temperature measurements show a marked diurnal pattern, Figure III-13, with peaks in the afternoon and lows in the morning, as might be expected in a shallow stream.

Figure III-14 shows the major ionic constituents and the water hardness as determined at the five gauging stations where the stream flow is more or less perennial. All the waters have quite high TDS levels with the tributaries exhibiting higher TDS than the main stream. Magnesium and sodium are the dominant cations; sodium is dominant on the main stream as shown at Stations 007 and 061, and magnesium is the dominant cation on the tributaries of Stewart Gulch and Willow Creek. Bicarbonate is the dominant anion at all locations except the West Fork Stewart Gulch where sulfate dominates.

Concentrations of major constituents in the surface streams are very similar to those in the alluvial wells. As in the alluvial wells, the surface water in West Fork of Stewart Gulch is the only place recorded where sulfate concentration is greater than bicarbonate. Thus while there is a rather constant ratio of bicarbonate to sulfate with sodium bicarbonate dominant along Piceance Creek, the waters of the West Fork of Stewart Gulch are slightly dominant in magnesium sulfate. Hem (1970) suggests that the principal cation in most fresh water is calcium. Within the C-b Tract region, calcium is generally third in abundance behind sodium and magnesium.

Tables III-4 through III-8 show the minimum, maximum and mean concentrations for selected water quality constituents through September 1975. Data of a similar nature through April had previously been presented in <u>Quarterly Data Report #3</u>. USGS Water Gauging Station 09306025 on the West Fork of Stewart Gulch exhibits the maximum reading for specific conductivity (2070 micromhos), the highest mean and the greatest minimum. It also had the lowest flowrate of the five stations. Dissolved oxygen is fairly constant from station to station and exhibits a narrow range of values, from a low of 5.0 mg/l (again at Station 025) to a high of 16.0 mg/l at Station 061; means for all stations fall within a range of 1.12 mg/l. All surface waters can be classified as hard (greater than 180 mg/l calcium carbonate equivalent).

Specific conductivity measures the ability of a solution to carry electrical current and is an indirect measure of total dissolved solids. For a stream which fits the simple dilution model for flow, conductivity will decrease with increasing flow because the increased flow resulting from surface runoff will carry a lower TDS load. Flow in the mainstream of Piceance Creek, as illustrated by Station 007 (Figure III-15), does show a slight trend toward lower conductivity with increasing flow, thus tending to confirm the dilution model for stream flow. Flow in the tributaries, however, illustrated by the Willow Creek Station 058 (Figure III-16), exhibits almost uniform conductivity regardless of flow. This indicates that these streams

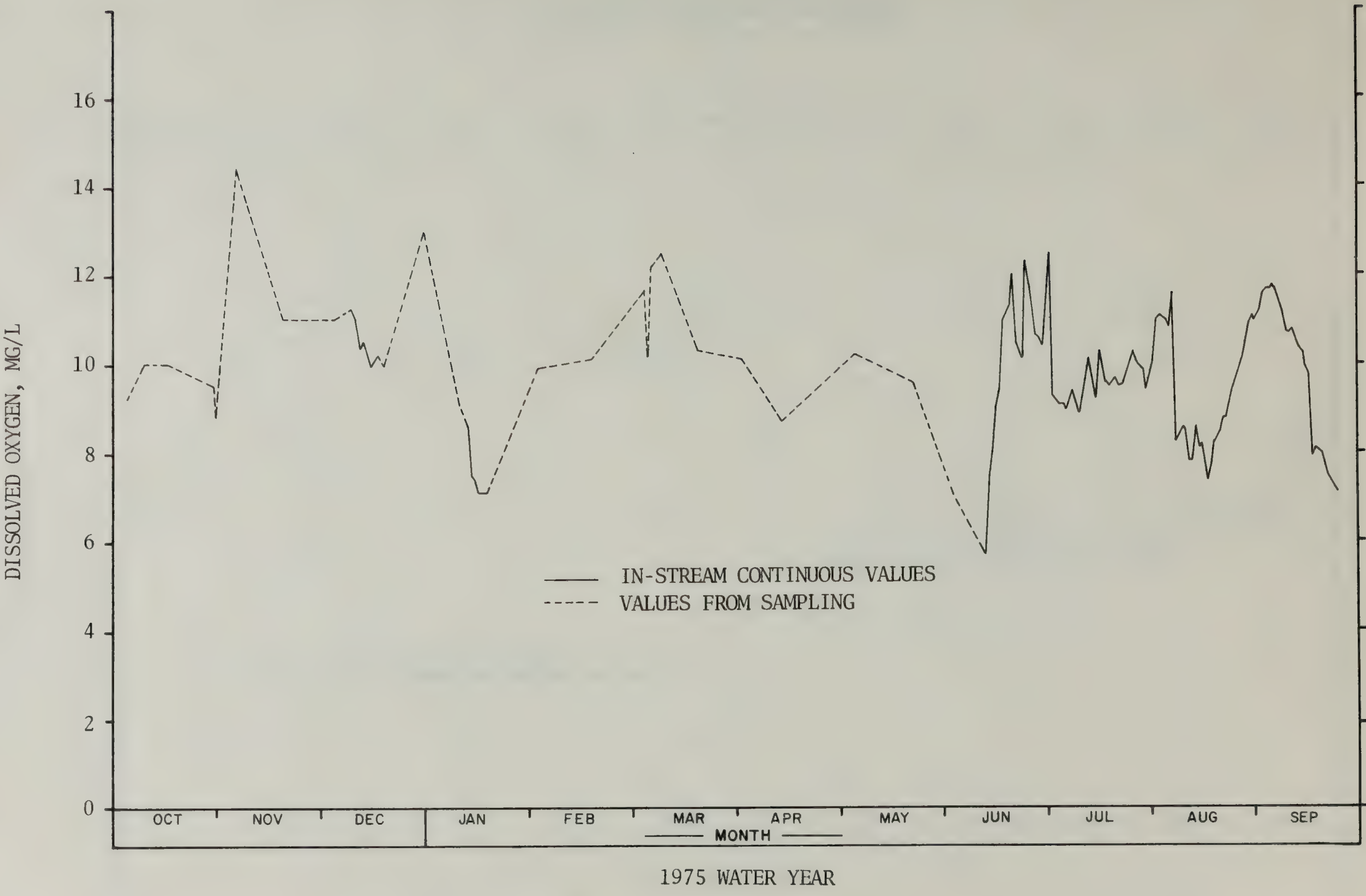


Figure III-8. DISSOLVED OXYGEN - PICEANCE CREEK BELOW RIO BLANCO (U.S.G.S. #09306007)

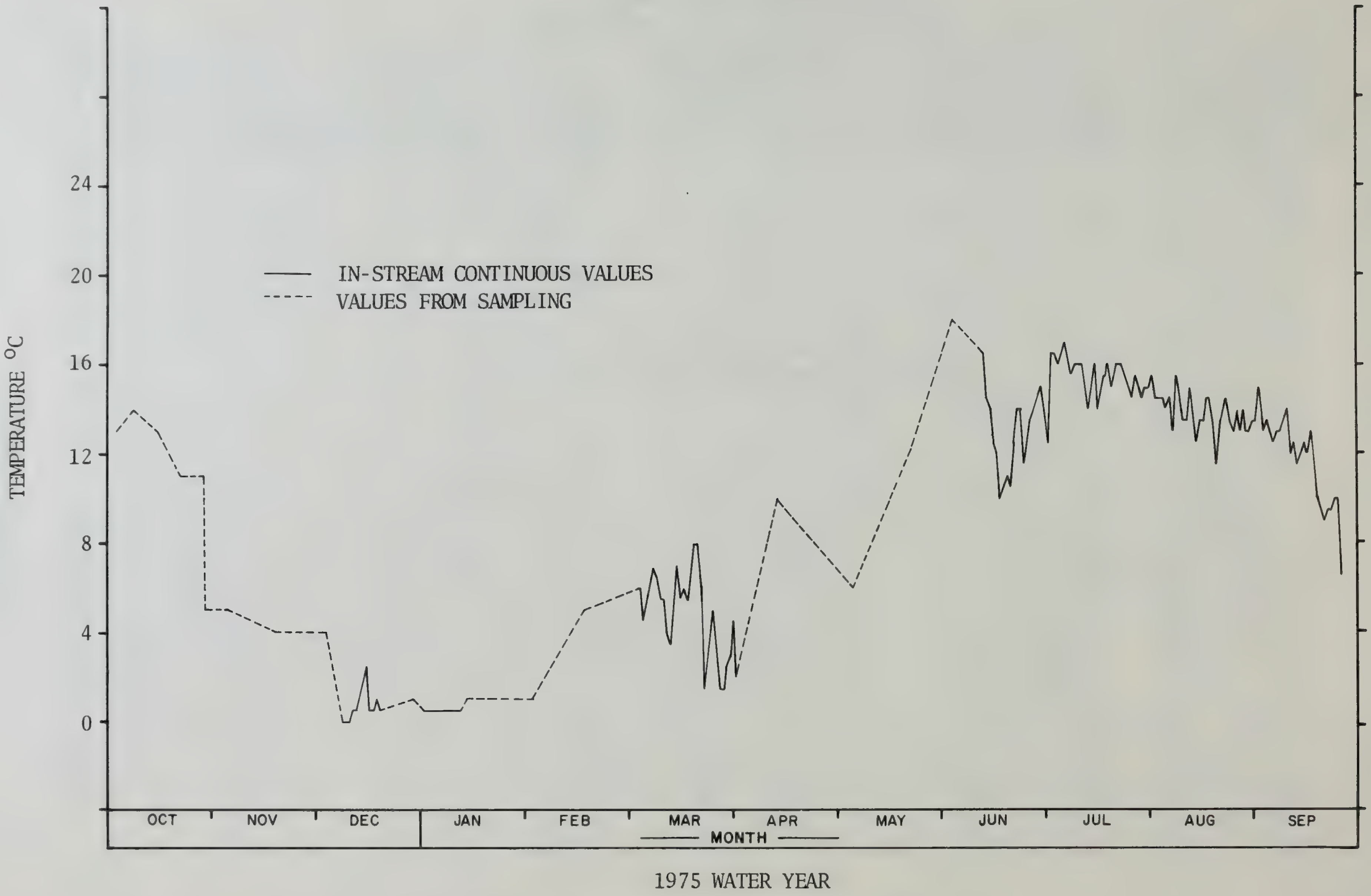


Figure III-9. STREAM TEMPERATURE - PICEANCE CREEK BELOW RIO BLANCO (U.S.G.S. #09306007)

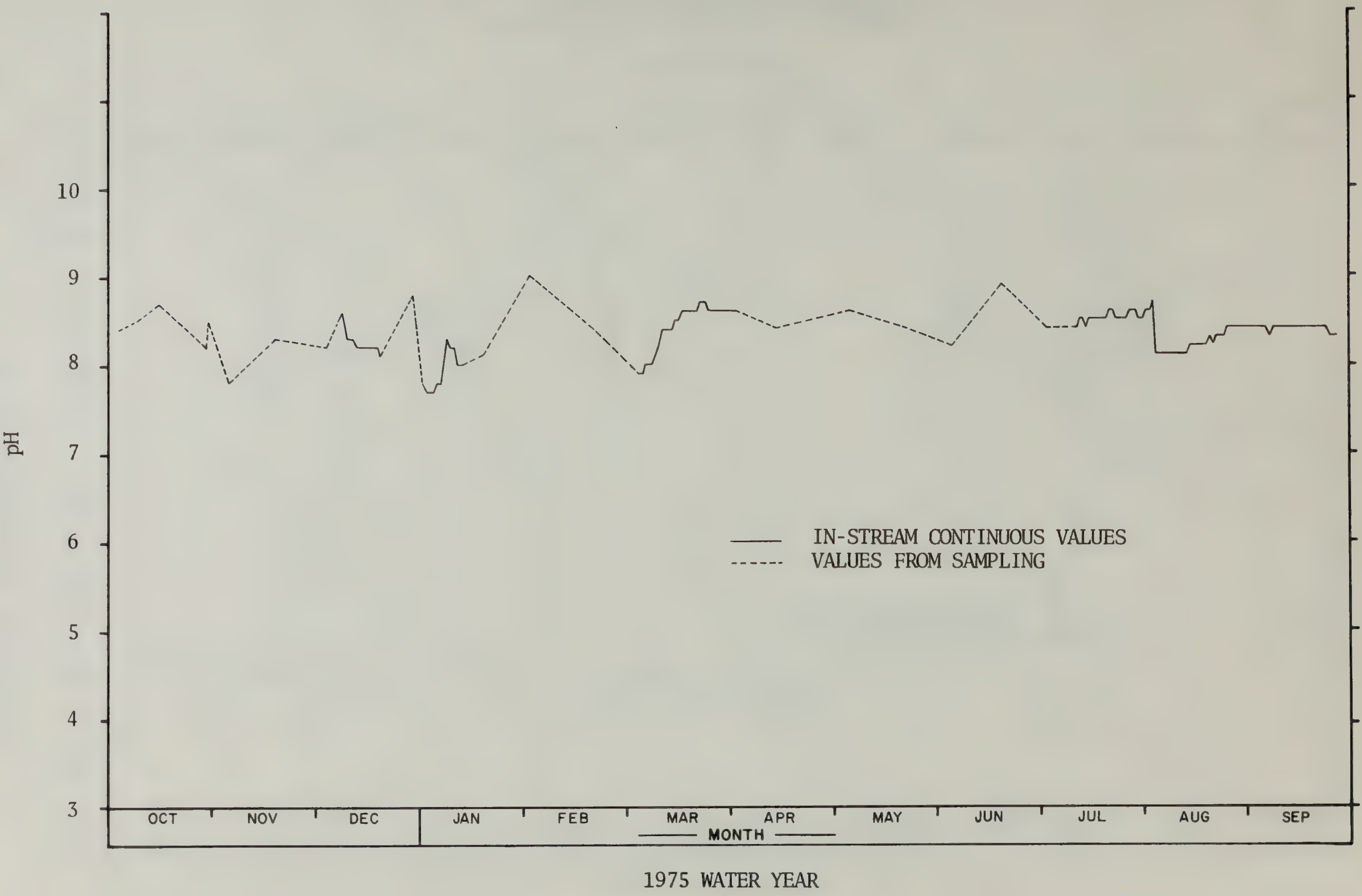


Figure III-10. pH - PICEANCE CREEK
BELOW RIO BLANCO
(U.S.G.S. #09306007)

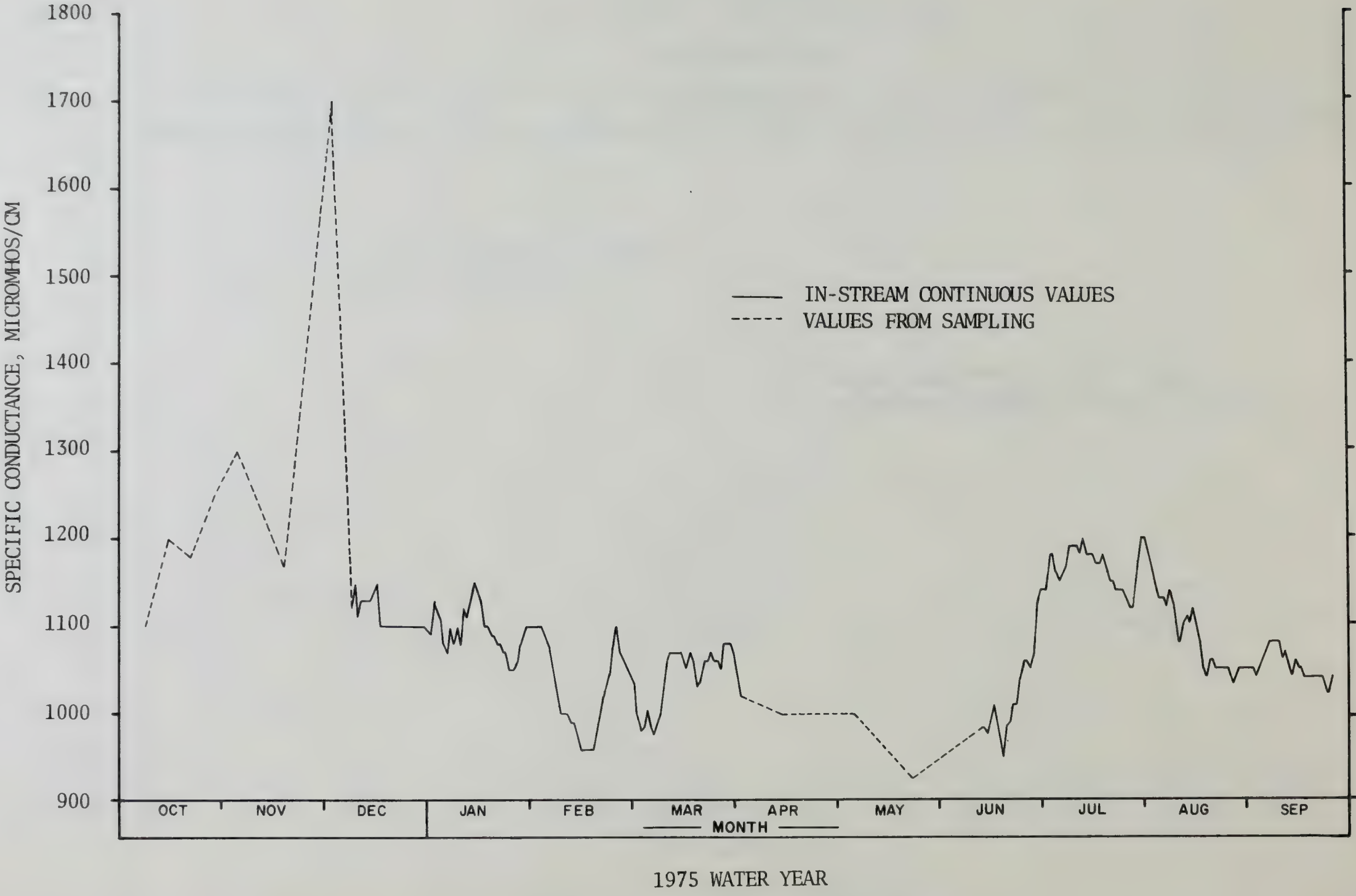


Figure III-11. SPECIFIC CONDUCTANCE - PICEANCE CREEK BELOW RIO BLANCO (U.S.G.S. #09306007)

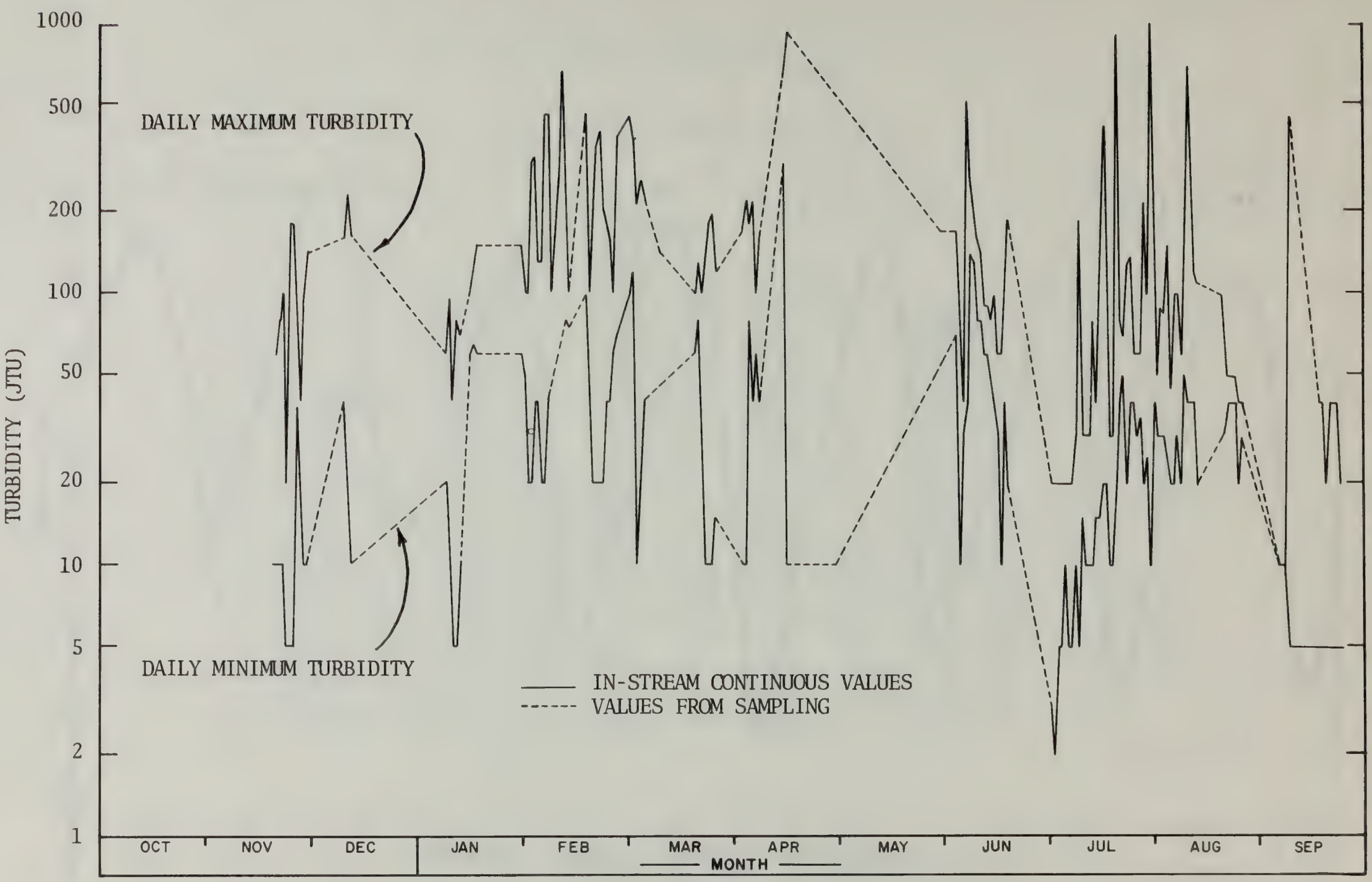


Figure III-12. MAXIMUM AND MINIMUM TURBIDITY - PICEANCE CREEK ABOVE HUNTER CREEK NEAR RIO BLANCO (U.S.G.S. #09306061)

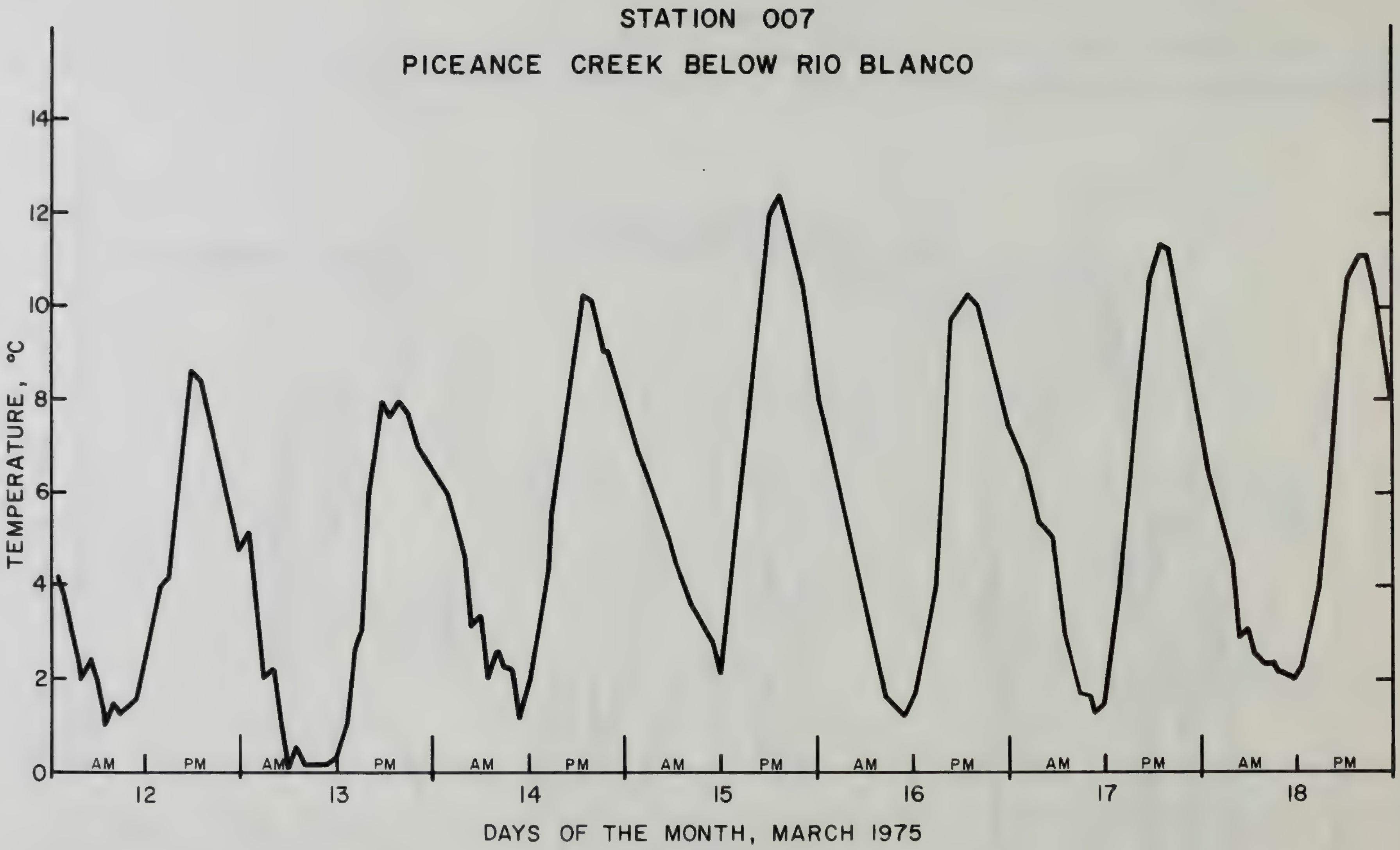


Figure III-13. DIURNAL TEMPERATURE VARIATIONS

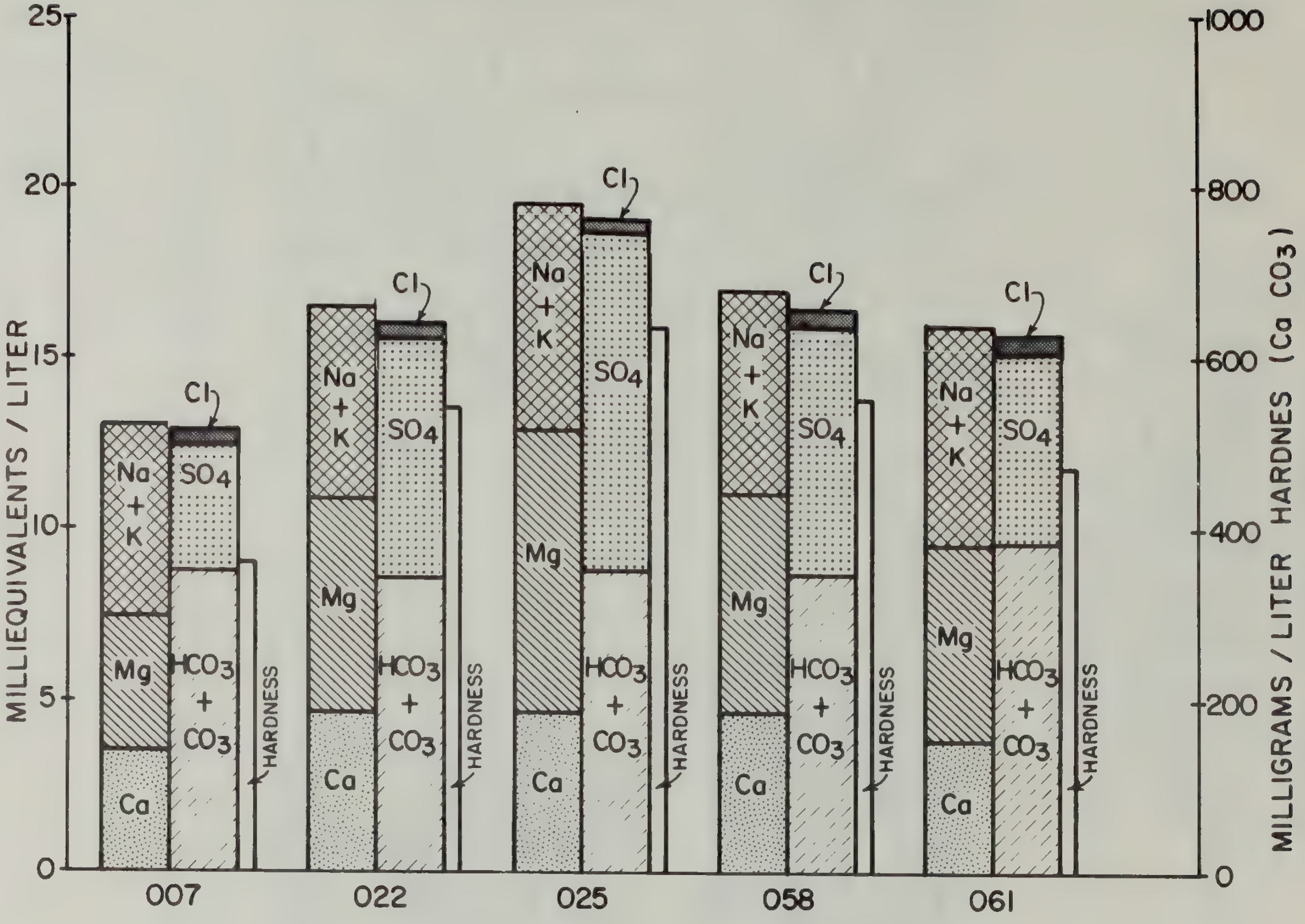


Figure III-14. DISTRIBUTION OF MAJOR IONS AT SURFACE WATER GAUGING STATIONS.

TABLE III-4
MINIMUM-MAXIMUM AND MEAN CONCENTRATIONS
FOR SELECTED WATER QUALITY CONSTITUENTS

U.S.G.S. NO. 09306061
PICEANCE CREEK AB HUNTER CREEK, Nr RIO BLANCO, CO.
April 23, 1974 to September 17, 1975
Elevation - 6214 ft. above MSL

Total No. of Samples		Minimum	Mean	Maximum
32	Discharge (CFS)	4.2	14	35
19	Turbidity (JTU) Dec. 1974-Sept. 75	3	100	670
38	Specific Conductivity (micro-mhos)	950	1370	1660
36	Dissolved Oxygen (mg/1)	6.4	9.61	16.0
39	Hardness (mg/1 $CaCO_3$)	350	470	570
38	Bicarbonate (mg/1)	440	580	690
42	Nitrate & Nitrite (as N) (mg/1) April 1974-September 1975	0.08	0.42	0.79
39	Calcium (mg/1)	59	78	88
39	Magnesium (mg/1)	46	68	88
39	Sodium (mg/1)	100	150	200
39	Potassium (mg/1)	1.2	4.1	6.4
39	Chloride (mg/1)	11	14	16
39	Sulfate (mg/1)	170	280	380
42	Fluoride (mg/1)	0.3	0.97	1.5
41	Boron (mg/1)	.120	.200	.320
36	Iron (ug/1)	10	81	880
36	Manganese (ug/1)	0	73	190

TABLE III-5
MINIMUM-MAXIMUM AND MEAN CONCENTRATIONS
FOR SELECTED WATER QUALITY CONSTITUENTS

U.S.G.S. NO. 09306058
WILLOW CREEK nr RIO BLANCO, CO.
April 23, 1974 to September 17, 1975
Elevation - 6273 ft. above MSL

Total No. of Samples		Minimum	Mean	Maximum
42	Discharge (CFS)	0.23	1.50	4.1
11	Turbidity (JTU) Dec. 1974-Sept. 75	2	20	72
40	Specific Conductivity (micro-mhos)	1100	1380	1590
40	Dissolved Oxygen (mg/1)	7.0	9.7	13.2
41	Hardness (mg/1 $CaCO_3$)	460	550	610
41	Bicarbonate (mg/1)	440	520	580
27	Nitrate & Nitrite (as N) (mg/1) April 1974-September 1975	0.10	0.42	2.0
41	Calcium (mg/1)	64	93	100
41	Magnesium (mg/1)	68	77	87
41	Sodium (mg/1)	110	130	180
41	Potassium (mg/1)	1.1	2.3	5.0
42	Chloride (mg/1)	9.3	11	14
41	Sulfate (mg/1)	310	360	500
28	Fluoride (mg/1)	0.3	0.4	1.3
26	Boron (mg/1)	.06	.11	.14
28	Iron (ug/1)	0	52	320
38	Manganese (ug/1)	0	17	70

TABLE III-6
MINIMUM-MAXIMUM AND MEAN CONCENTRATIONS
FOR SELECTED WATER QUALITY CONSTITUENTS

U.S.G.S. NO. 09306025
WEST FORK STEWART GULCH NEAR RIO BLANCO, CO.
May 3, 1974 to November 20, 1974
May 7, 1975 to September 4, 1975
Elevation - 6668 ft. above MSL

Total No. of Samples		Minimum	Mean	Maximum
23	Discharge (CFS)	<0.01	<0.13	0.06
9	Turbidity (JTU) Dec. 1974-Sept. 75	1	8.1	16
30	Specific Conductivity (micro-mhos)	1160	1610	2070
26	Dissolved Oxygen (mg/1)	5.0	8.7	13.5
28	Hardness (mg/1) ($CaCO_3$)	530	620	820
30	Bicarbonate (mg/1)	440	520	760
31	Nitrate & Nitrite (as N) (mg/1) April 1974-September 1975	0.00	0.12	1.3
28	Calcium (mg/1)	48	91	130
28	Magnesium (mg/1)	74	98	120
28	Sodium (mg/1)	130	160	220
28	Potassium (mg/1)	0.9	3.2	9.8
28	Chloride (mg/1)	6.5	11	29
30	Sulfate (mg/1)	380	480	590
30	Fluoride (mg/1)	0.0	0.35	1.2
29	Boron (mg/1)	.040	.11	.16
25	Iron (ug/1)	20	58	210
25	Manganese (ug/1)	0	4.5	20

TABLE III-7
MINIMUM-MAXIMUM AND MEAN CONCENTRATIONS
FOR SELECTED WATER QUALITY CONSTITUENTS

U.S.G.S. NO. 09306022
STEWART GULCH ab WEST FORK nr RIO BLANCO, CO.
September 12, 1974 to September 17, 1975

Total No. of Samples		Minimum	Mean	Maximum
25	Discharge (CFS)	1.3	2.3	8.1
20	Turbidity (JTU) Dec. 1974-Sept. 75	0	10.7	30
30	Specific Conductivity (micro-mhos)	750	1360	1750
30	Dissolved Oxygen (mg/1)	7.2	9.7	14.0
30	Hardness (mg/1 $CaCO_3$)	460	550	610
30	Bicarbonate (mg/1)	430	505	780
30	Nitrate & Nitrite (as N) (mg/1) September 1974-September 1975	0.01	1.5	1.9
30	Calcium (mg/1)	73	93	99
30	Magnesium (mg/1)	64	77	95
30	Sodium (mg/1)	120	130	250
30	Potassium (mg/1)	1.1	1.7	2.5
30	Chloride (mg/1)	6.0	7.5	16.0
30	Sulfate (mg/1)	330	370	490
30	Fluoride (mg/1)	0.1	0.60	3.3
32	Boron (mg/1)	.030	.086	.530
25	Iron (ug/1)	10	57	620
25	Manganese (ug/1)	0	12	40

TABLE III-8
MINIMUM-MAXIMUM AND MEAN CONCENTRATIONS
FOR SELECTED WATER QUALITY CONSTITUENTS

U.S.G.S. NO. 09306007
PICEANCE CREEK BELOW RIO BLANCO, CO.
April 23, 1974 to September 17, 1975
Elevation - 6366 ft. above MSL

Total No. of Samples		Minimum	Mean	Maximum
38	Discharge (CFS)	1.4	10.3	36
20	Turbidity (JTU) Dec. 1974-Sept.75	0	54.9	480
43	Specific Conductivity (micro-mhos	825	1110	1540
41	Dissolved Oxygen (mg/1)	6.9	9.8	13.0
45	Hardness (mg/1 $CaCO_3$)	290	370	420
44	Bicarbonate (mg/1)	390	530	620
45	Nitrate (NO_3) (mg/1) April 1974-September 1975	0.00	0.33	2.50
45	Calcium (mg/1)	51	69	79
45	Magnesium (mg/1)	34	47	57
45	Sodium (mg/1)	75	130	160
45	Potassium (mg/1)	2.4	3.7	19
45	Chloride (mg/1)	9.0	15	24
44	Sulfate (mg/1)	110	160	200
45	Fluoride (mg/1)	0.2	1.1	1.3
43	Boron (mg/1)	.11	.21	.33
39	Iron (ug/1)	10	81	390
38	Manganese (ug/1)	10	113	230

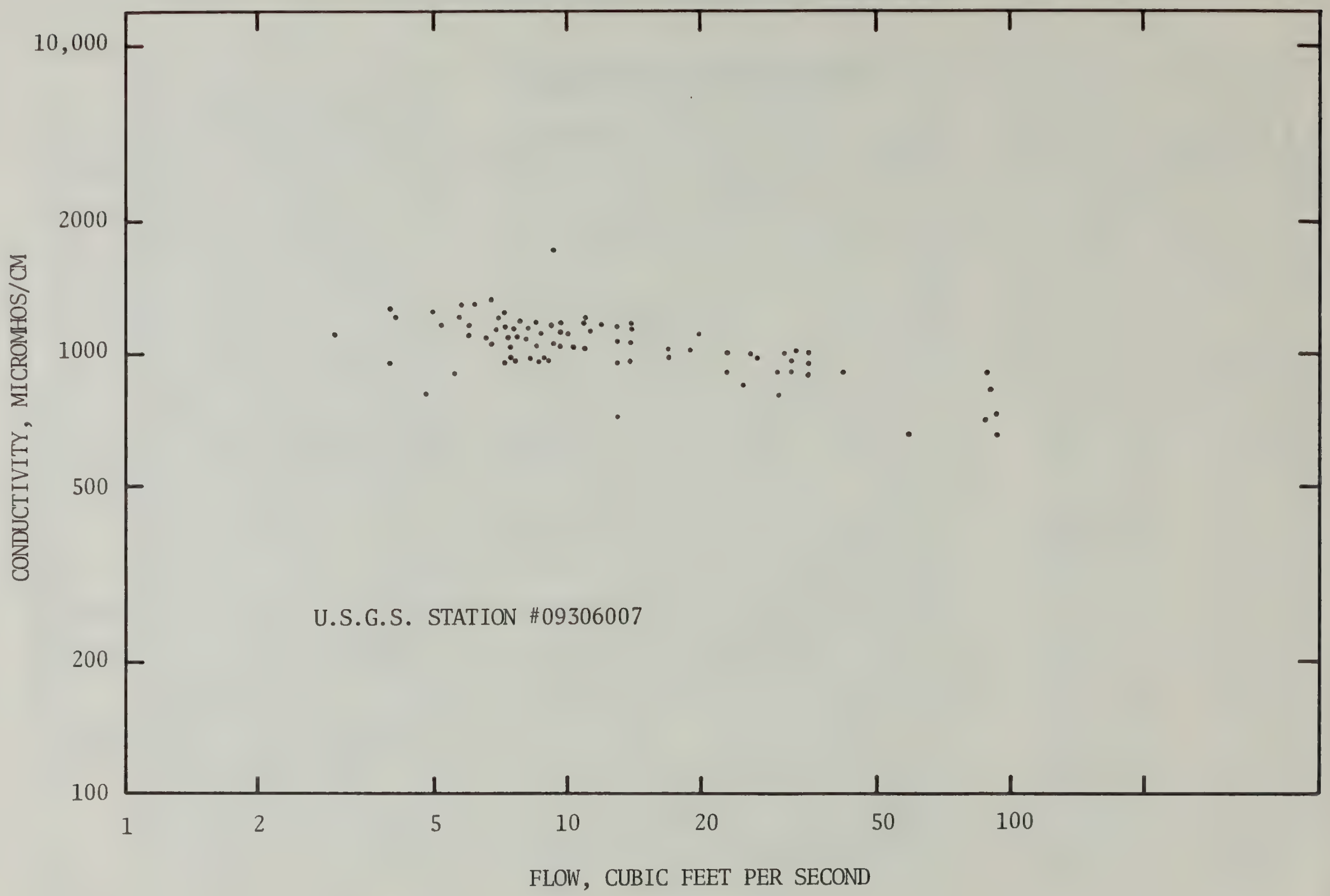


Figure III-15. CONDUCTIVITY VERSUS FLOW, MAINSTREAM PICEANCE CREEK

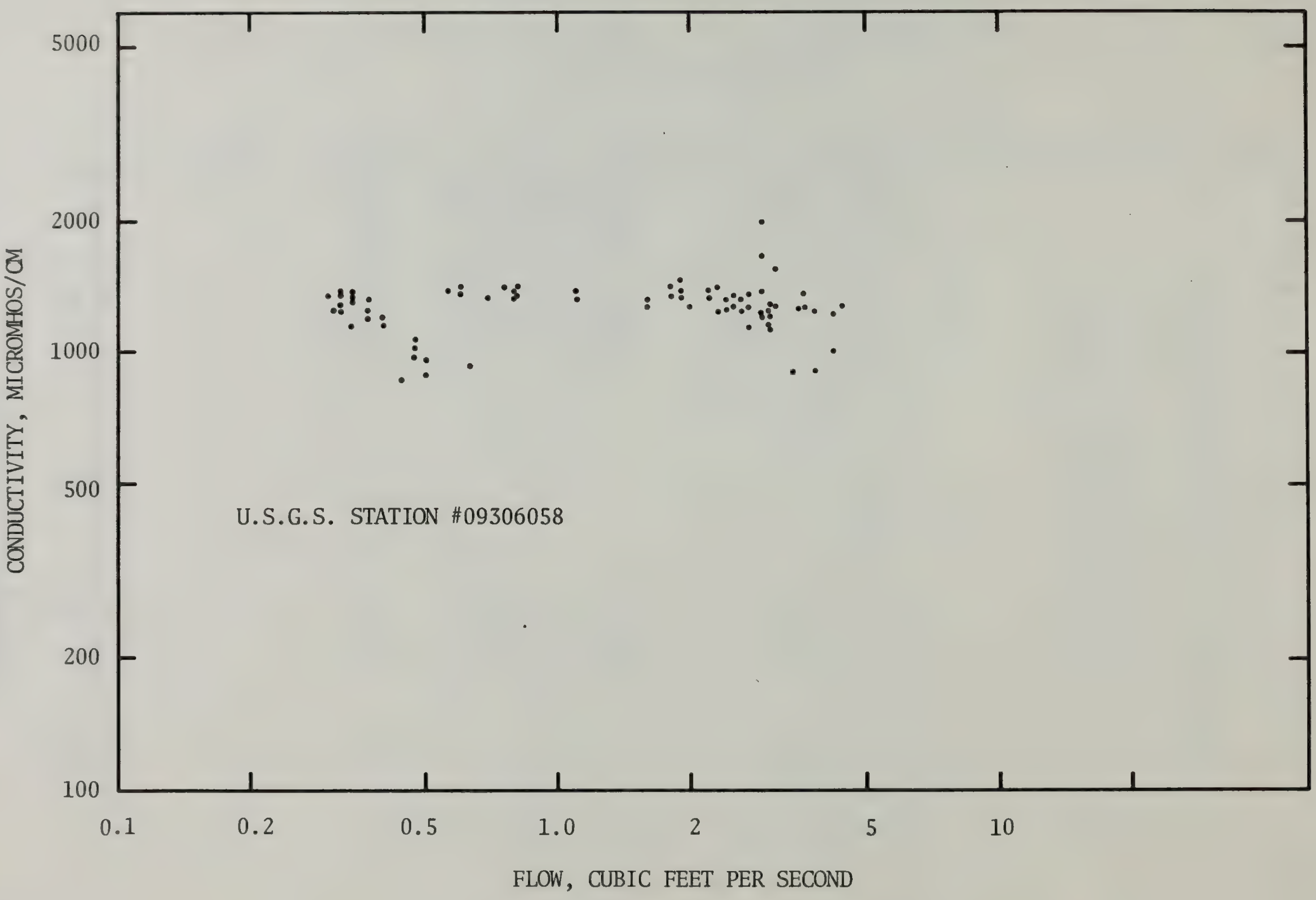


Figure III-16. CONDUCTIVITY VERSUS FLOW, TRIBUTARY TO PICEANCE CREEK

carry few pollutants from other than natural sources.

An indication of the degree of pollution of a stream can be obtained by plotting a pollution index, such as dissolved oxygen, against flow. For a heavily polluted stream, dissolved oxygen would be expected to increase with flow because of dilution. Data from Stations 007 and 061, plotted in Figures III-17, do not exhibit the characteristics of a heavily polluted stream.

In Figure III-18 sediment concentration is plotted against flow on log-log paper for Station 061. This shows that, in general, the sediment load increases with increasing flow. This again confirms the model of a stream with base flow originating from springs, and therefore, having a lower sediment load than the surface runoff waters which account for increased flows.

To show the relationships between flow rate and TDS content several chronological plots of ion concentration were made over the same time period (examples are shown in Figures III-19 through III-22). Stations 007 and 061 on Piceance Creek showed the same general pattern. Little change was seen in the concentrations of the various constituents as a function of flow during 1975. The data for 1974 exhibited a definite increase in the concentrations of dissolved solids at low flows. This could be interpreted as a classic dilution effect (where the base stream flow originates from groundwater sources with a high TDS content). During periods of storm runoff or snowmelt, the addition of higher quality runoff water results in a diluting effect and a lower concentration of dissolved solids. The increase in TDS during the irrigation season also can be related to the irrigation process and the leaching from the fields being irrigated. Based on the observed differences between 1974 and 1975 water-year data, the flow in Piceance Creek during relatively wet years is high enough that the dissolved solids concentration remains unaffected by irrigation and also overshadows the input from highly saline springs and seeps. During low-flow years, these factors begin to assert themselves.

Several of the trace elements being monitored have been found only in very low concentrations, near the lower limit of detectability. These values are below United States Public Health Service (USPHS) standards for drinking water. Table III-9 compares those values observed to date with these standards. Sampling frequency will probably be changed from semi-monthly to quarterly or annual sampling in the future. Research on the inorganic constituents of natural water has shown that the ion proportions are near constant or adequately related to the flow and that the ion concentrations are deterministically related to the conductivity. Once the estimates of ion proportions are made within acceptable confidence limits, inorganic water quality can be determined from conductivity, which is being measured on a continuous basis. Only in the case of suspected pollution would sampling be necessary.

Some of the maximum fluoride readings are in excess of the limits set forth by the USPHS, however, mean concentrations for all stations

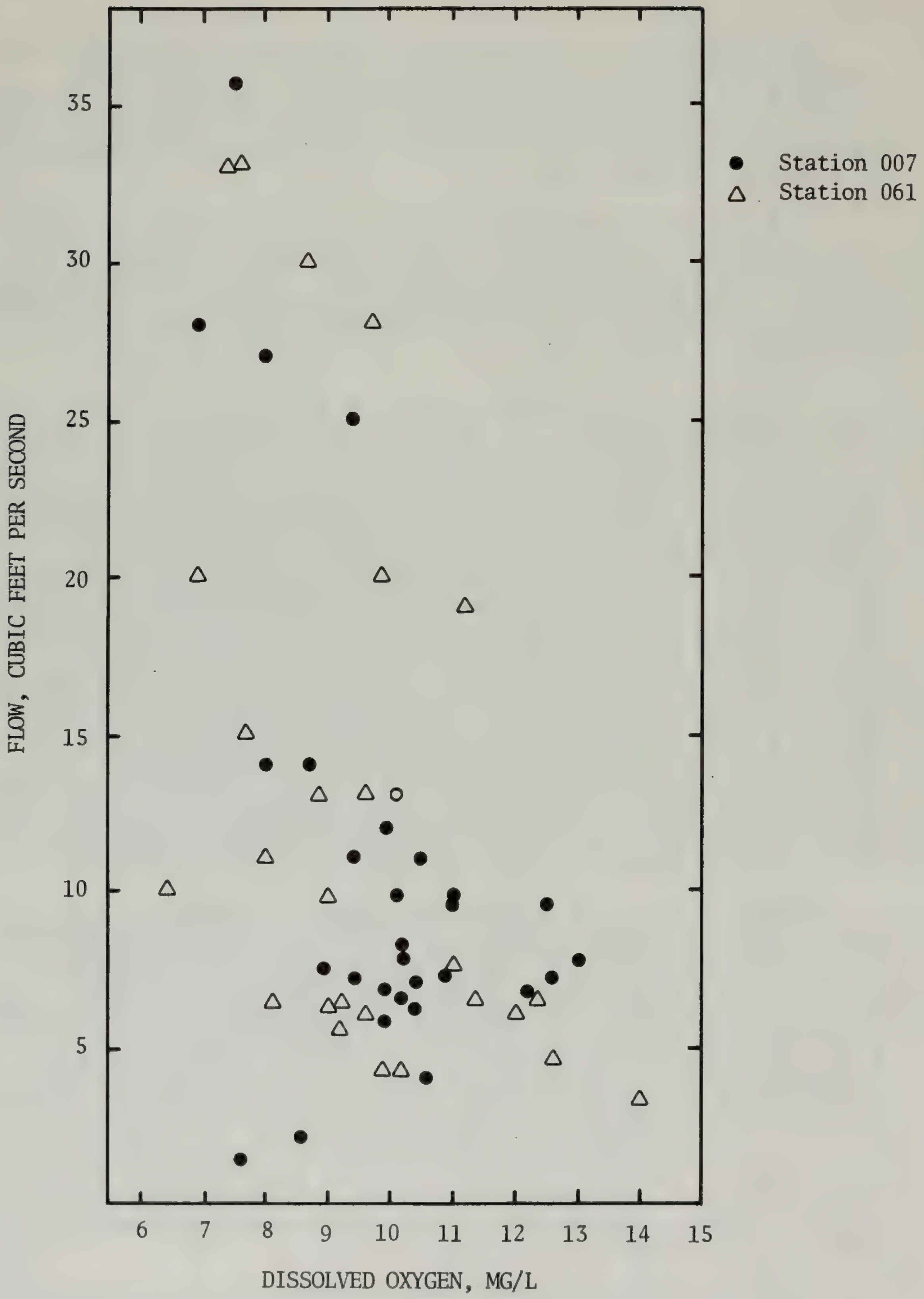


Figure III-17. DISSOLVED OXYGEN VERSUS FLOW

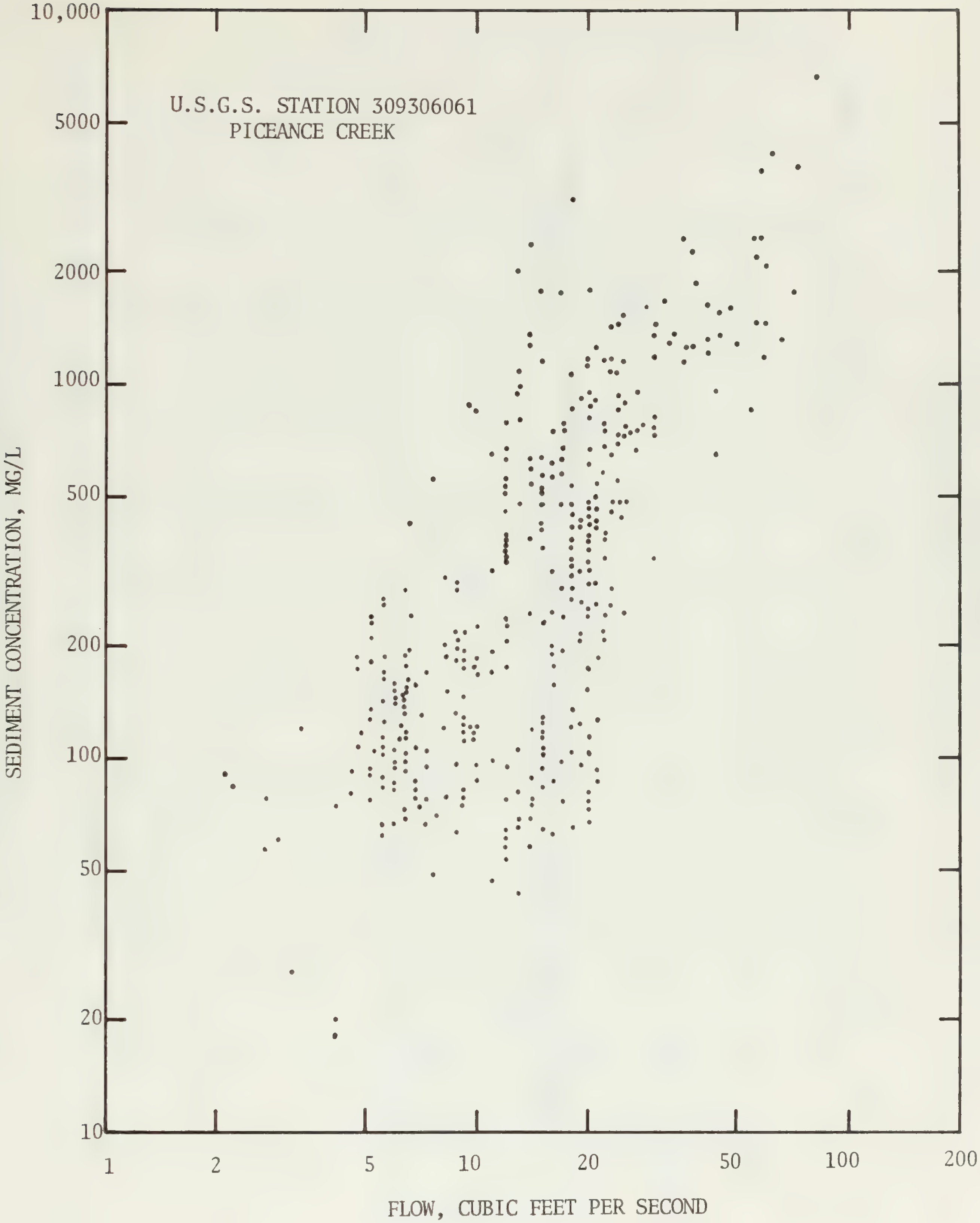


Figure III-18. SEDIMENT CONCENTRATION VERSUS FLOW

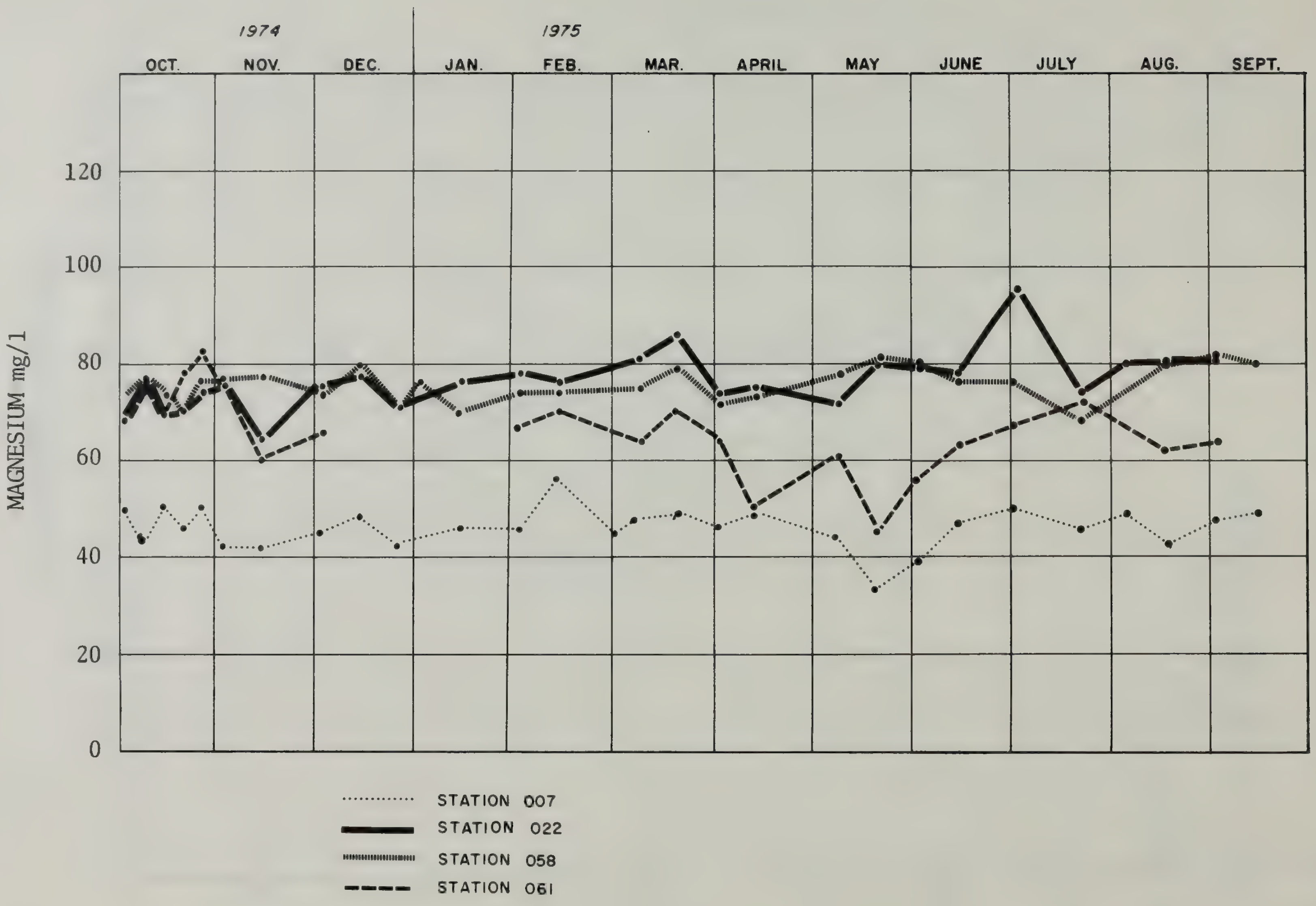


Figure III-19. MAGNESIUM CONCENTRATION
SURFACE WATER GAUGING STATIONS,
TRACT C-b AREA

Figure III-20. SULFATE CONCENTRATION
SURFACE WATER GAUGING STATIONS,
TRACT C-b AREA

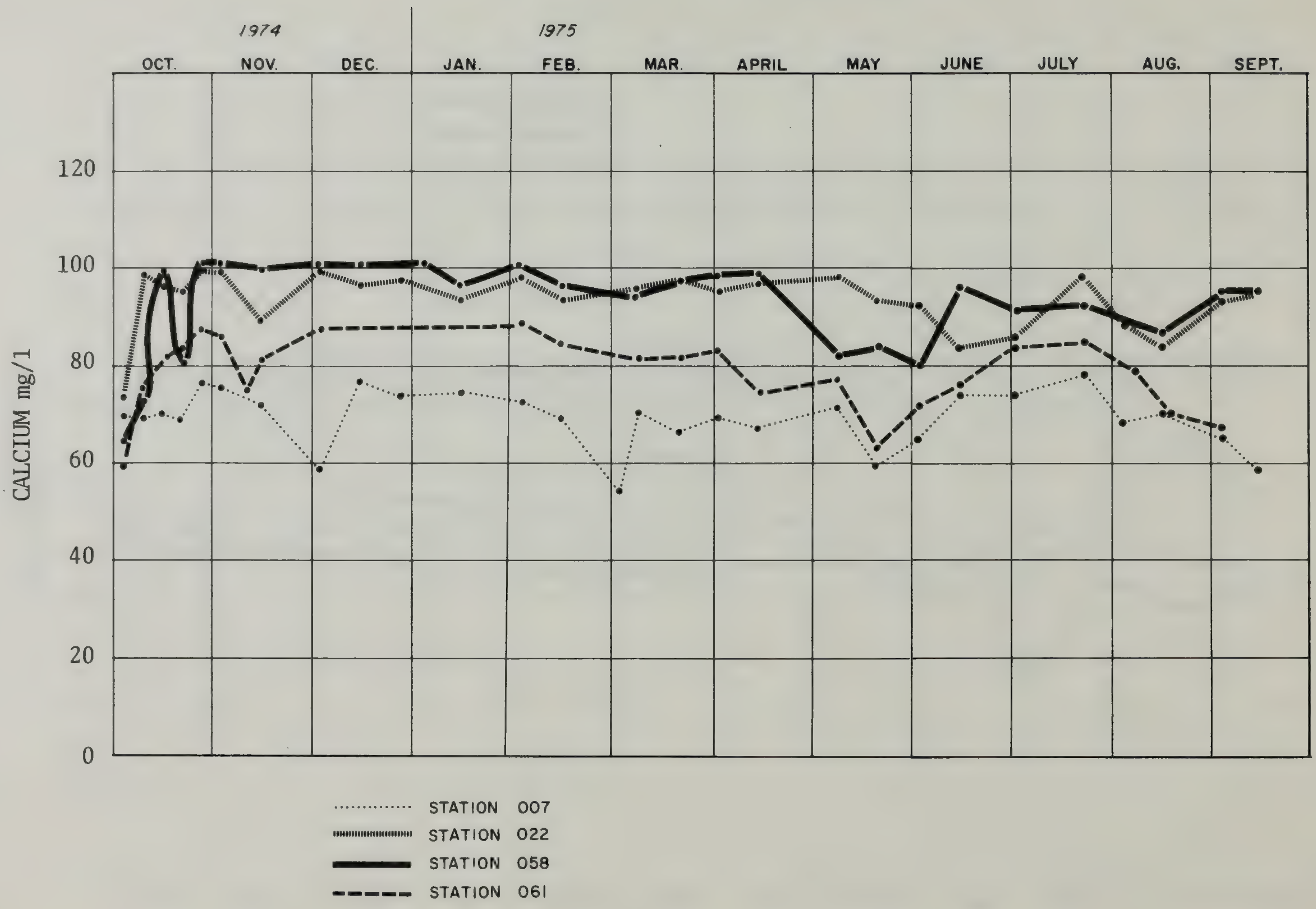


Figure III-21. CALCIUM CONCENTRATION SURFACE WATER GAUGING STATIONS, TRACT C-b AREA

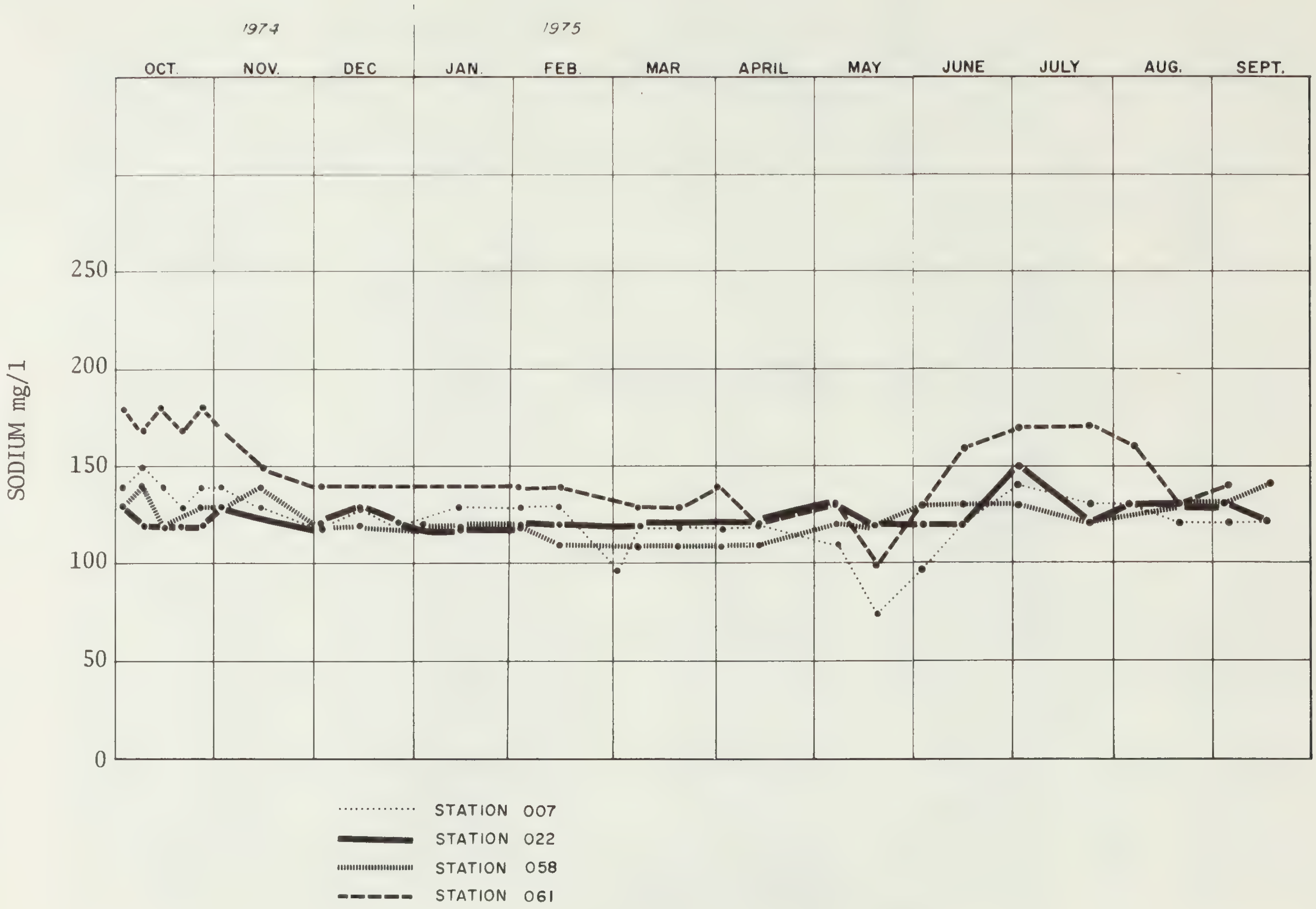


Figure III-22. SODIUM CONCENTRATION
SURFACE WATER GAUGING STATIONS,
TRACT C-b AREA

Table III-9 COMPARISON OF SURFACE WATER QUALITY TO DRINKING WATER STANDARDS
Concentrations in Milligrams/Liter
(April 1974 – April 1975)

Element	Minimum **	Maximum	Public Health Limit
arsenic	0	0.006	0.05*
barium	0	0.200	1.0*
cadmium	0	0.020	0.01*
chromium	0	0.020	0.05*
copper	0	0.020	1.0
cyanide	0	0.01	0.2*
lead	0	0.020	0.05*
lithium	0	0.056	***
mercury	0	0.0009	0.002
selenium	0	0.005	0.01*
zinc	0	0.370	5.0

* Drinking water standards – rejection of water supply if exceeded.
** A value of zero implies a concentration below the lower limit of detectability for the analytical method used.
*** No standards set.

are within the limits of the drinking water standards. For agricultural standards the boron content is not excessive except for the most sensitive of crops. The suggested limits for drinking water for iron and manganese are often exceeded particularly in the main stream, Piceance Creek. Since the drinking water limits are higher than those for some industrial uses, surface water of this part of the Piceance Basin would require treatment for industrial uses.

C. Springs

1. Monitoring Sites

Figure III-23 shows the locations of springs and seeps near the Tract which are being sampled. No significant seeps or springs have been found on the Tract itself. Table III-10 gives the locations of springs studied by the Colorado Division of Water Resources and their correspondence to those shown in Figure III-23.

2. Flow Records

Figures III-24 and III-25 are hydrographs of the flow recorded by Parshall flumes stationed near four of these springs. Although the flows are somewhat variable, no pronounced cyclic pattern can be discerned in the record to date. Springs W-1 and W-3 are both in the Willow Creek drainage and appear to have corresponding flow patterns. The same can be said for S-1 and CER-6, which are both in the Stewart Gulch drainage.

3. Water Quality

Table III-11 presents a summary of the major chemical constituents and water quality parameters based on samples from the springs in the fall of 1974 and again in the fall of 1975. Although at first there appeared to be some minor differences in the level of various constituents seen in the Willow Creek springs versus the Stewart Gulch springs, repeat sampling has shown the analytical variability to be as large as the postulated differences. At the present time there does not seem to be any statistically significant differentiation in the chemical analyses of the springs and all must be presumed to come from basically the same source.

The spring waters are fairly high in dissolved solids and total hardness. The distribution of major ions in terms of milli-equivalents is shown in Figure III-26. No single anion or cation is completely dominant and the water would have to be described as a mixed bicarbonate-sulfate and sodium-calcium-magnesium type. Although none of the mean values for trace elements exceed Public Health or EPA standards for water supply systems, the levels of boron, iron, fluoride and manganese are high. Individual sample analyses for these elements sometimes exceed the allowable values.

Table III-10 LOCATIONS OF SPRINGS AND SEEPS

Identification of Water Resources Division Springs

Designation	I.D.#	Location	Corresponding Identification in Figure IX–4
S–l and S–1–A *	1081 1082	Lat 039° 49' 30" Lon 108° 11' 07"	S1, S3 and S5
CER–6**	1063	Lat 039° 48' 25" Lon 108° 10' 34"	S2 and S4
W–1	1078	Lat 039° 50' 20" Lon 108° 14' 35"	S6 and S7
W–2	1110	Lat 039° 47' 36" Lon 108° 14' 59"	S9
W–3	1079	Lat 039° 47' 17" Lon 108° 15' 03"	S10

* These springs are close by. Single flume measures the discharge from both the springs.

** This is a measuring site. Measure flow from two upstream springs.

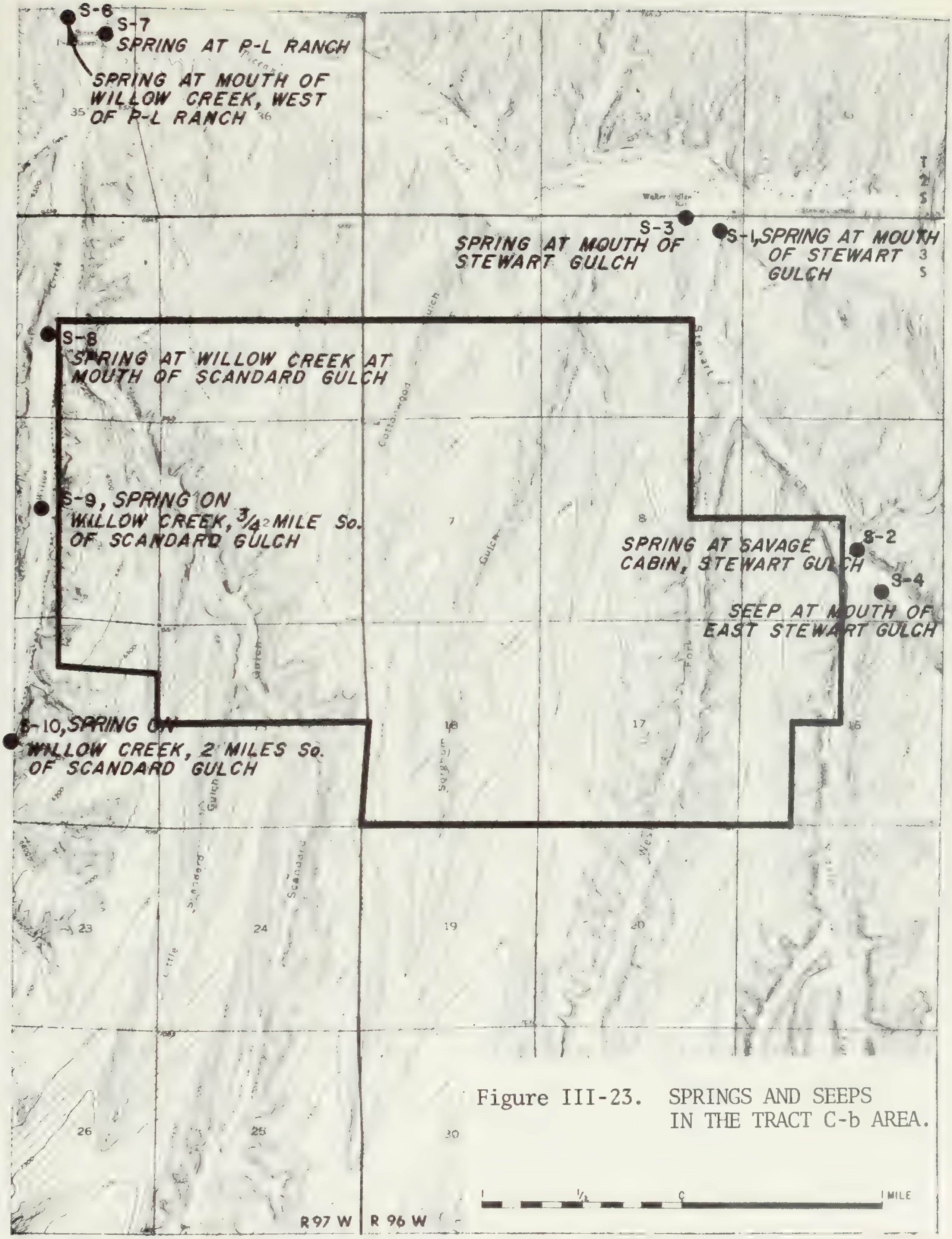


Figure III-23. SPRINGS AND SEEPS IN THE TRACT C-b AREA.

Figure III-24. HYDROGRAPH - SPRINGS
S-1 AND CER-6.

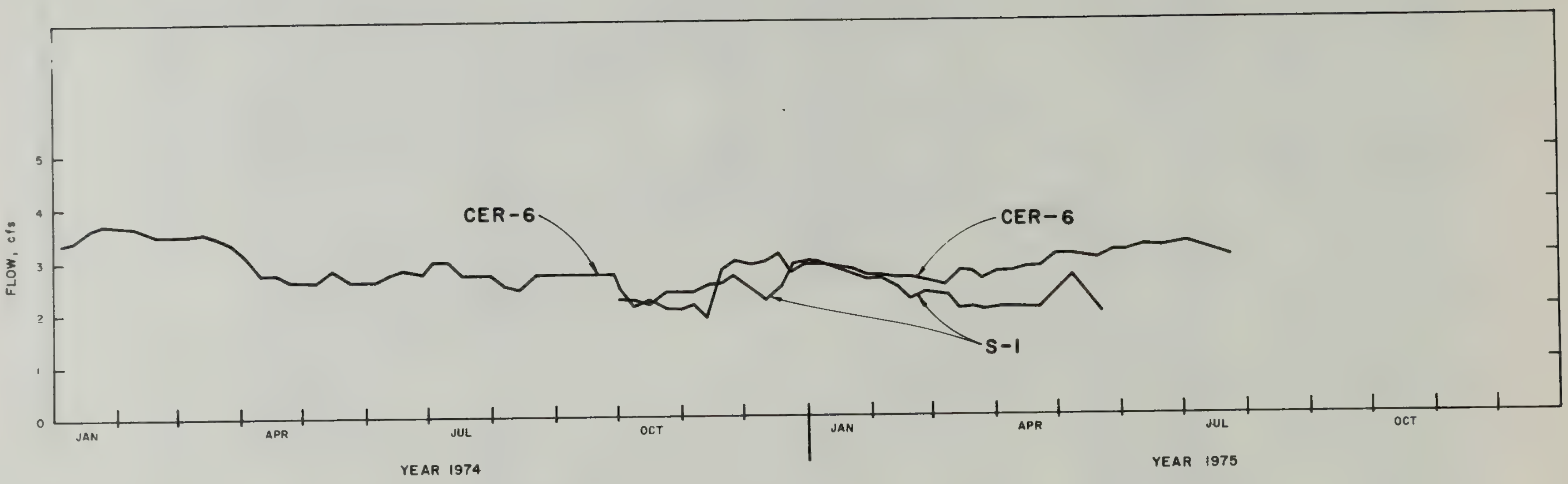


Figure III-25. HYDROGRAPH - SPRINGS
W-1 AND W-3.

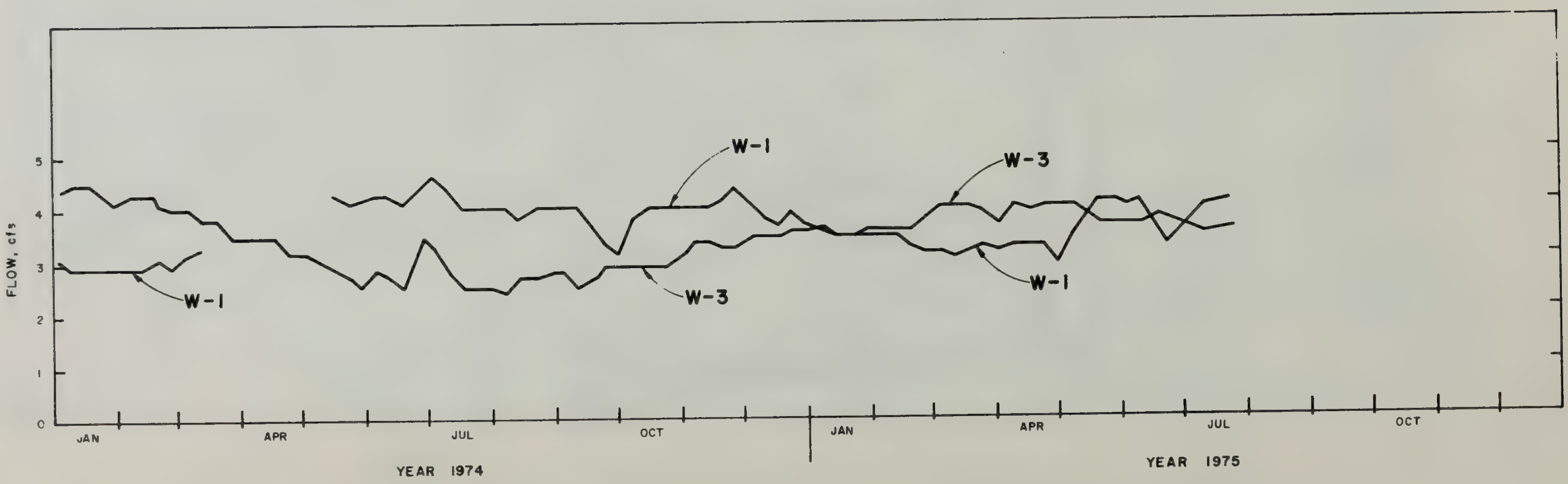


Table III-11

SELECTED WATER QUALITY CONSTITUENTS - SPRINGS & SEEPS

Chemical Analyses in mg/l

	Minimum	Maximum	Mean	Median
Conductance	1100	1400	1300	1200
pH	7.3	8.4	8.0	8.0
Dissolved Solids	800	1130	970	970
Hardness	380	590	530	520
Organic Carbon		6	2.9	3.0
Aluminum		3	0.65	0.35
Ammonia		0.4	0.17	0.10
Arsenic			0.005	0.003
Barium		0.06	0.033	0.030
Bicarbonate	420	650	520	520
Boron	0.1	1.6	0.63	0.40
Bromine		0.08	0.03	0.03
Calcium	48	160	95	94
Carbonate		7	1.6	0.1
Chloride	1	17	6.4	5.0
Cobalt		0.05	0.011	0.005
Fluoride	0.1	2.1	0.72	0.55
Iron			0.87	0.09
Lead		0.05	0.02	0.01
Manganese		0.2	0.04	0.02
Mercury		0.002	0.0006	0.0003
Molybdenum		0.2	0.045	0.03

Table III-11 Continued

	Minimum	Maximum	Mean	Median
Nickel		0.08	0.015	0.010
Nitrate	0.1	8.1	3.3	2.2
Potassium	1.1	2.3	1.7	1.7
Rubidium	0.004	0.04	0.011	0.009
Scandium		0.01	0.005	0.005
Silica	12	21	16	15
Sodium	90	240	140	140
Strontuim	0.9	5.0	2.6	2.0
Sulfate	290	440	350	350
Titanium	0.02	0.6	0.24	0.20
Vanadium		0.009	0.004	0.004
Zinc	0.01	0.4	0.11	0.07

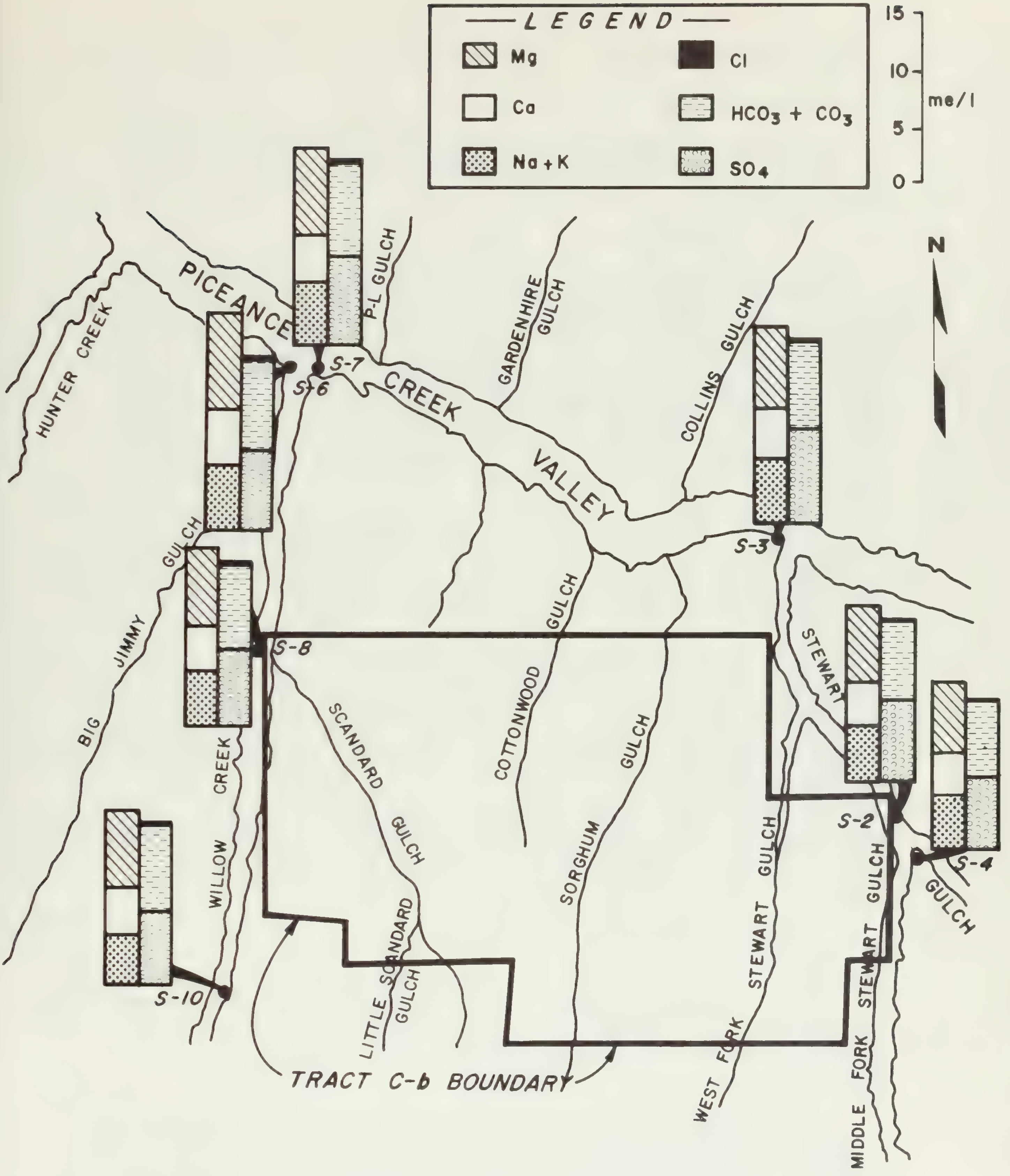


Figure III-26.

DISTRIBUTION OF MAJOR IONS IN SPRINGS

D. Alluvial Wells

1. Locations

A total of 13 alluvial observation wells were drilled on and near the Tract in 1974. Designated A-1 through A-13, their locations were shown in Figure II-1. Two of these wells, A-4 and A-13, are dry holes.

2. Water Levels

Data from the first year of observations are insufficient to draw any firm conclusions regarding water level fluctuations in the alluvial aquifer. However, some tentative patterns may be seen. These data are plotted in Figure III-27. All wells show a June-July peak water level. This is probably the delayed result of maximum infiltration and recharge from the snowmelt runoff period which occurs approximately two months earlier. The size of this peak depends upon the up-gradient underflow as well as local recharge. Wells such as A-5, A-9, A-11 and A-12 have limited underflow because of their location near the valley walls or at the mouth of dry gulches with only a thin mantle of alluvial material.

Following the mid-year peak all wells show a decline during the summer months. The first low occurs in either September or October depending on the well's location in the valleys and its relation to major underflow. Alluvial well #1 located in the Piceance Creek valley at the mouth of P/L Gulch shows a sharp but steady decline from the mid-year high. All other wells have a second peak occuring as early as September in Well A-3 and as late as December in Well A-2. In most wells, the reason for the second "generally lower" peak is assumed to be the delayed result of precipitation which occurred in June and July (See Chapter VII, Figure VII-5). The soil moisture chart (See Chapter VII, Figure VII-6) shows two peaks, one in April related to snowmelt and one in June relating to the early summer rain. These two peaks relate well to the two water-level highs noted in most of the alluvial wells. Further data over the second year of baseline studies may help to clarify this suggested relationship. Most wells experienced a steady decline in water level following the second peak. This decline is expected to reverse late in the winter months as snowmelt begins to reach the saturated alluvium.

3. Pump Tests

Alluvium is a potential source of water in the perennial stream valleys of the Piceance Basin. As much as 140 feet thick, the alluvium is generally saturated below stream level. High well yields have been reported--as large as 1500 gpm--but the limited areal extent of the alluvium restricts high discharge rates to brief periods.

The alluvium is made up of sands, gravels and clays eroded from the sandstones, siltstones and marlstones of the Uinta Formation. These deposits in Piceance Creek across the northern boundary of the C-b Tract are less than 0.5 miles wide. The depth to bedrock, established by the alluvial well drilling program, varies from 14 feet at A-13 in upper

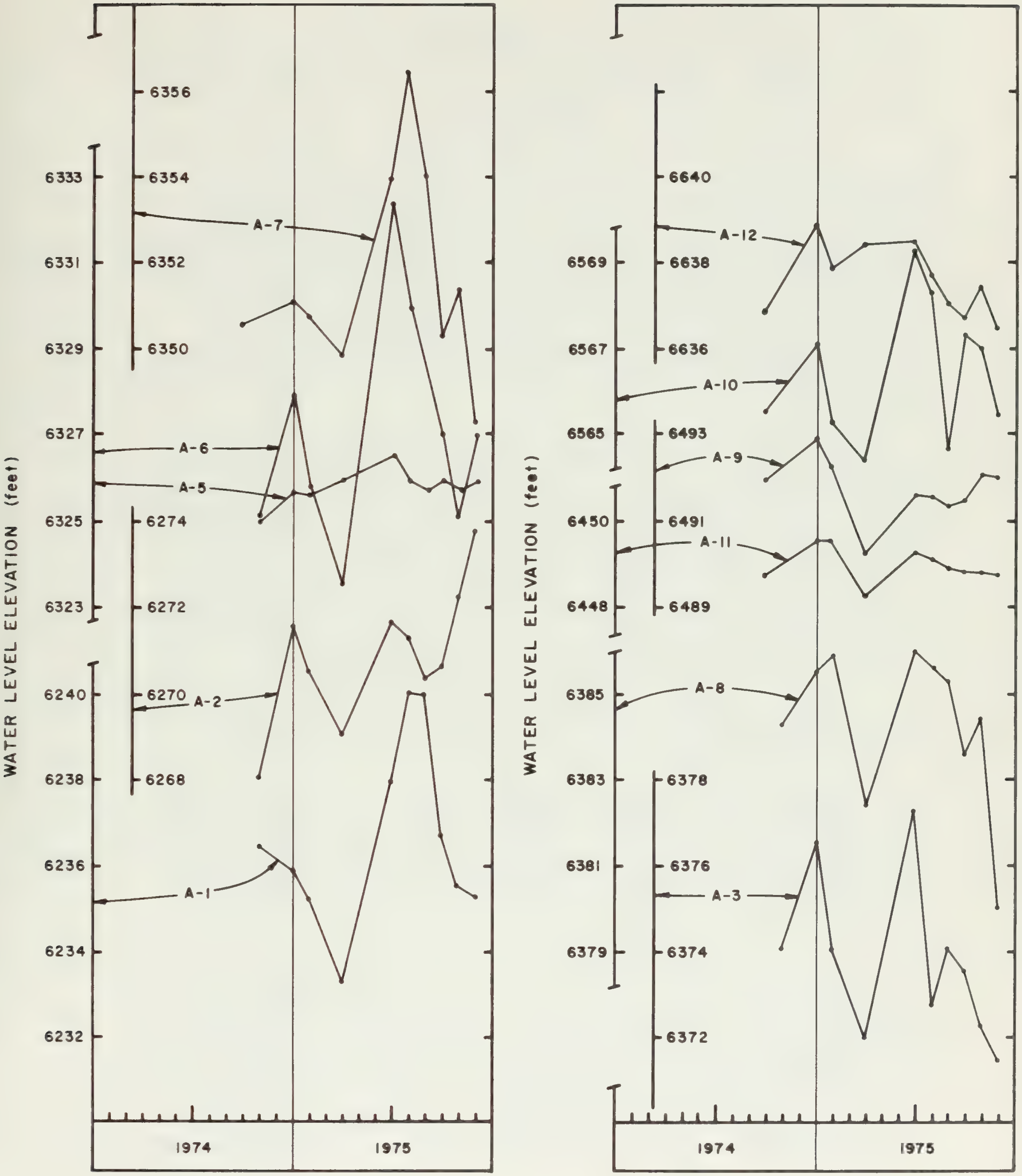


Figure III-27. WATER LEVEL DATA, ALLUVIAL WELLS

Sorghum Gulch to 112 feet at A-3 in lower Scandard Gulch. The thickness of the alluvium in Piceance Creek valley varies from 51 feet in A-7 to 109 feet in A-1. Average thickness of the alluvium in Piceance Creek as determined by wells is approximately 77 feet. Saturated thickness is given in Table II B-3 of the Summary Report #5.

In October, 1975, pump tests were conducted on the eleven alluvial wells which yield water. In these tests the pumped well also served as the observation well. The Theis recovery method, using a modified equation for an unconfined aquifer, was used to evaluate the aquifer parameters. Drawdown data were also collected and analyzed by the type curve method of Glover (1974) to calculate maximum pumpage and the time required to reach maximum draw-down for the given discharge. Results are given in Table II B-3 of the Summary Report #5. Since the calculations are valid only for infinite aquifers and under other assumptions used in the development of the flow equations, the values listed in Table II B-3 (Summary Report #5) must be considered as approximations only.

Being deposited in a narrow valley such as Piceance Creek, the stream alluvium is intermixed with alluvial fan deposits at the mouths of the tributaries and with colluvial deposits toward the edges of the valley. These disruptions in the homegeneity of the deposits have an effect on the transmissivity of the alluvial aquifers. Weeks, et al (1974) report ranges of transmissivity from 2700 to 20,000 ft^2/day in the alluvium of Piceance Creek. The total range in transmissivity calculated from the C-b tests was from a low of 121 ft^2/day at A-9 in Stewart Gulch to a high of 10,000 ft^2/day at A-10 in the Middle Fork of Stewart Gulch. These figures, while not exactly comparable to those reported by Weeks, are generally within the lower range of his values.

Earlier pump tests in A-1 and A-2 were analyzed using the Jacob formula from a semi-log plot. Transmissivities were 1348 ft^2/day for A-1 and 359 ft^2/day for A-2.

An analysis of the data presented in Table II B-3 (Summary Report #5) with respect to the location of the well shows no correlation between the data and the specific stream system. Other factors not discernible from the surface are involved. Such factors include the stratigraphy of the alluvium and the occurrence of clay beds as well as the geologic boundaries of the aquifer.

4. Water Quality

Most of the alluvial wells have now been sampled three times--in the fall of 1974 and in the spring and fall of 1975. The chemical analyses (Table III-12) show a marked similarity to the results for the springs and seeps. As illustrated by the Collins diagrams in Figure III-28 (and the Stiff diagrams in Figure III-29), the distribution of major ions in milli-equivalents per liter is similar to that for the springs in Figure III-26. While Weeks, et al. (1974) classify the alluvium water in the Piceance Basin as a sodium bicarbonate type, the

TABLE III-12
SELECTED WATER QUALITY CONSTITUENTS

ALLUVIAL WELLS
CHEMICAL ANALYSES IN mg/l

	Min	Max	Mean	Median
Conductance	1000	1800	1300	1300
PH	7.3	8.7	8.1	8.3
Dissolved Solids	720	1300	1000	1100
Hardness	330	690	470	500
Organic Carbon	1.0	9.0	4.6	3.0
Aluminum	0.01	3.0	0.42	0.14
Ammonia	0.1	5.2	0.6	0.2
Arsenic	0.001	0.05	0.006	0.004
Barium	0.02	0.6	0.09	0.04
Bicarbonate	360	670	500	500
Boron	0.1	5.2	0.72	0.50
Bromine	0.02	0.1	0.04	0.03
Calcium	16	100	64	64
Carbonate		23	6.3	4.5
Chloride	4	27	10	7
Cobalt			0.01	0.004
Fluoride	0.13	5.0	0.97	0.50
Iron			0.62	0.05
Lead	0.003	0.2	0.026	0.01
Magnesium	20	120	80	83
Manganese	0.003	2.3	0.34	0.09
Mercury	0.0001	0.048	0.0034	0.0002
Molybdenum	0.005	0.2	0.035	0.020
Nickel	0.003	0.1	0.021	0.01
Nitrate	0.1	9.1	3.1	2.9
Potassium	1	5	1.8	2.0
Rubidium	0.002	0.06	0.017	0.01
Scandium		0.01	0.004	0.004
Silica	11	41	17	15
Sodium	93	730	200	160
Strontium	0.4	10	2.0	2.0
Sulfate	200	530	390	410
Titanium	0.01	2.0	0.39	0.25
Vanadium	0.002	0.2	0.014	0.005
Zinc	0.01	2.0	0.34	0.20

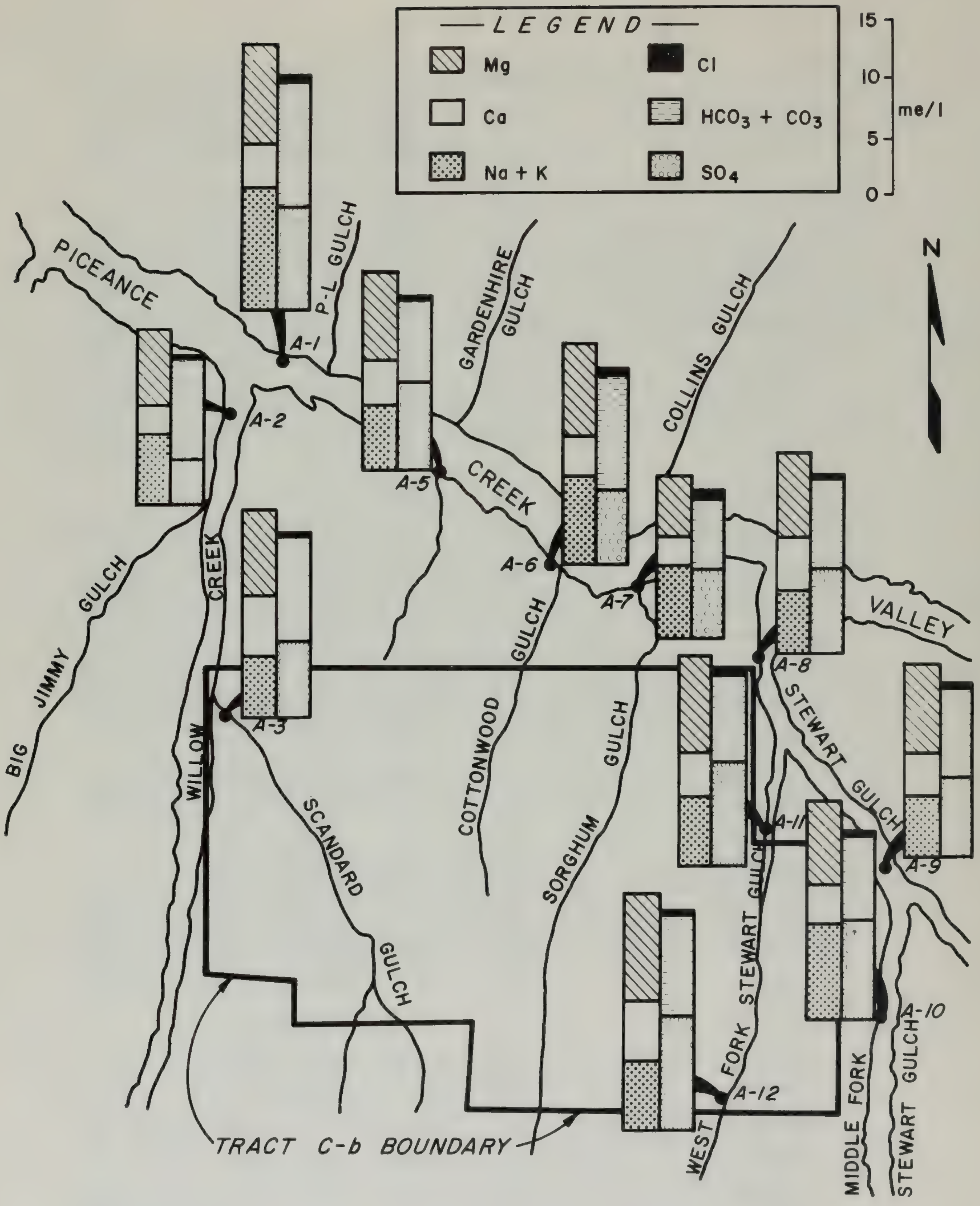
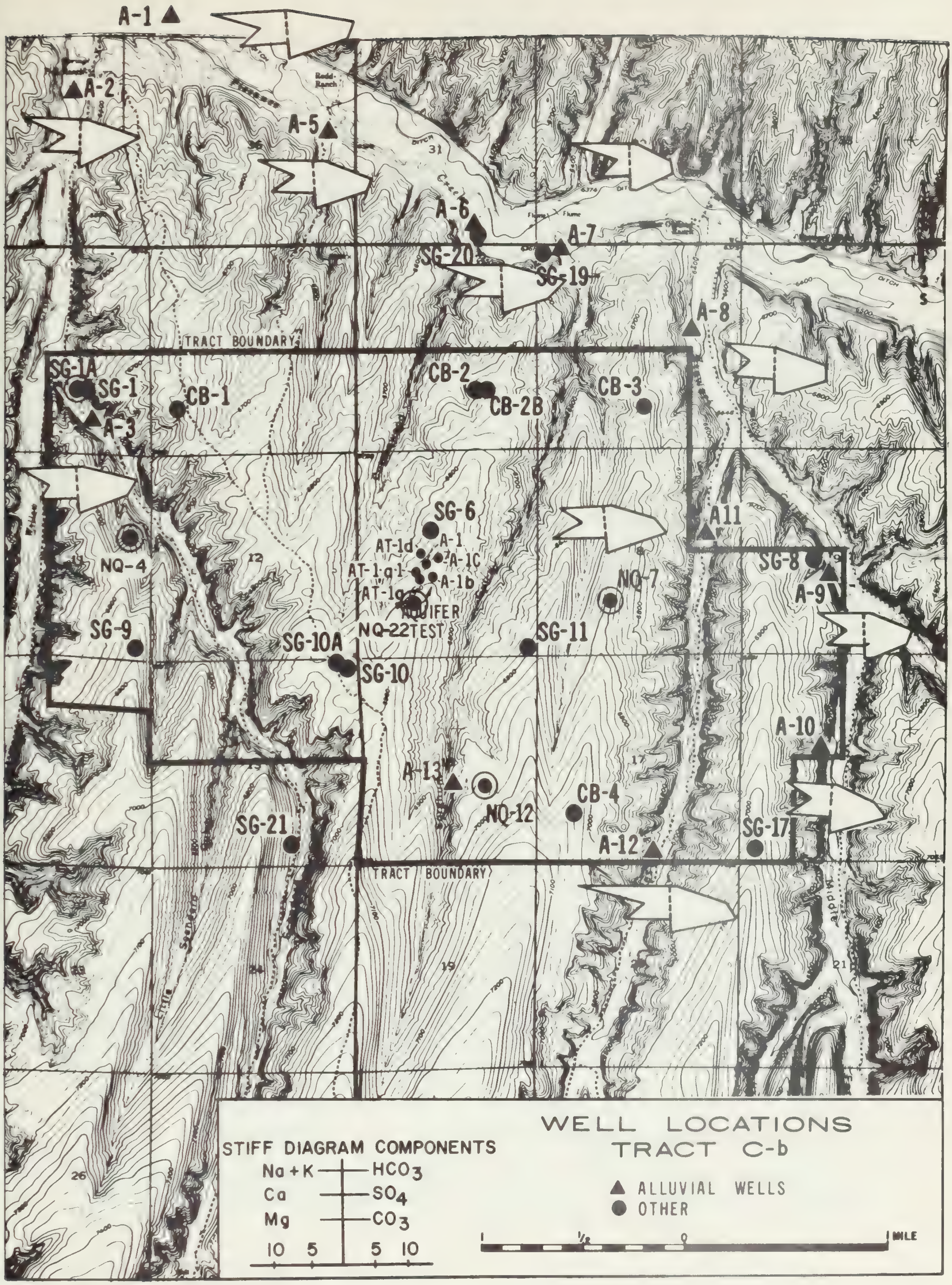


Figure III-28.

DISTRIBUTION OF MAJOR IONS IN ALLUVIAL WELLS



STIFF DIAGRAMS FOR ALLUVIAL WELLS Figure III-29.

water in the alluvium near Tract C-b is a mixed type. Sulfate levels are approximately equal to bicarbonate levels.

The concentration of dissolved solids averages 1000 mg/l with a range of 720 to 1300 mg/l. Weeks, et al. reported an average dissolved solids content of 1750 mg/l over a much broader range of values, 470 to 6720 mg/l. Weeks, et al. also reported "very high" concentrations of fluoride (greater than 9.8 mg/l) and hydrogen sulfide gas in wells located near faults. They felt that those substances implied communication with the lower aquifer. The water samples from C-b alluvial wells were not sampled for hydrogen sulfide gas, but the typical, rotten-egg smell attributable to hydrogen sulfide has not been reported. The maximum concentration of fluoride reported in the C-b alluvial wells was 5 mg/l which would be an excessive concentration for drinking water. However most of the high fluoride readings were reported in the first sampling run which may imply analytical or sampling problems at that time. Similarly, all of the recordings of lead content, all but one of the iron content and most of the manganese readings which exceeded the standards set by the Public Health Service were obtained in the first sampling run.

No general pattern of differences between spring and fall readings appears nor is there a consistent change with time. The data available do not yet cover a long enough time period to define such trends, if any. A point-by-point comparison between Tables III-11 and III-12 reveals the striking correspondence between alluvial and spring waters. In no case, with the minor exception of calcium, is the difference between the mean values more than a fraction of one standard deviation for the alluvial samples.

E. Deep Wells

1. Locations and Completions

Locations of the various core holes, observation wells and test wells were given in Figure II-1. The well depths and completions are presented in Figures III-30 and III-31 as they relate to the Tract stratigraphy. Several of the wells have multiple tubing strings, perforated in different zones. Those strings completed in the upper aquifer (above the Mahogany zone) are shown in Figure III-31 and those open to the lower aquifer are shown in Figure III-30. These figures represent the well configurations through September, 1975, at which time the most recent samples were taken. Since then, Wells SG-8, SG-10, SG-11 and SG-17 have been reworked to seal off their lowest portions, which had penetrated a thin, highly saline water zone. All chemical data discussed in this report, however, pertain to the configurations shown in Figures III-30 and III-31. A summary of monitoring wells by zone is given in Table III-13.

2. Drilling Water Production

As a part of the general well histories, a record was maintained of the water discharged during drilling. A representative portion of these

Figure III-30. WELL COMPLETIONS IN THE LOWER AQUIFER.

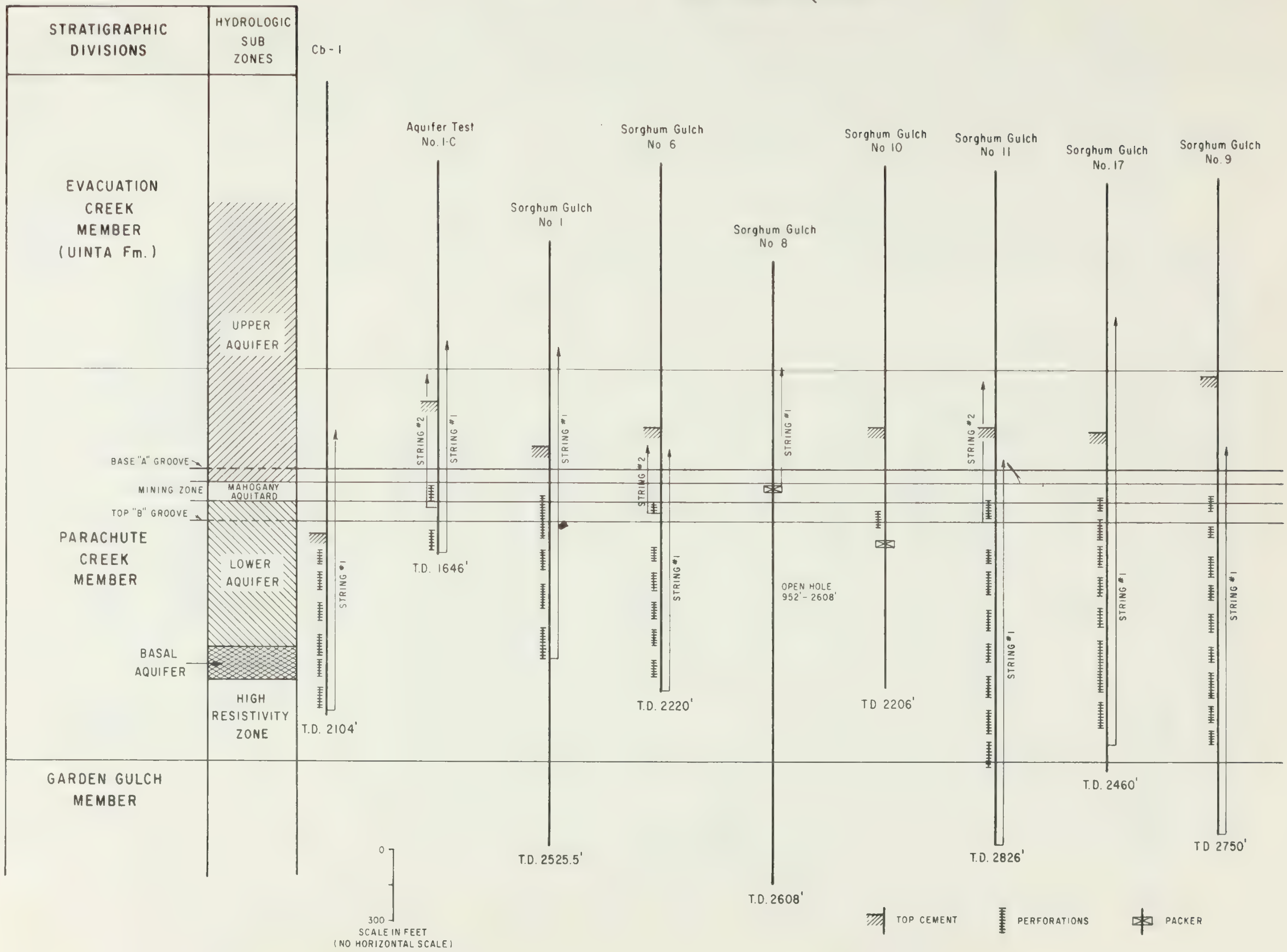


Figure III-31. WELL COMPLETIONS IN THE UPPER AQUIFER.

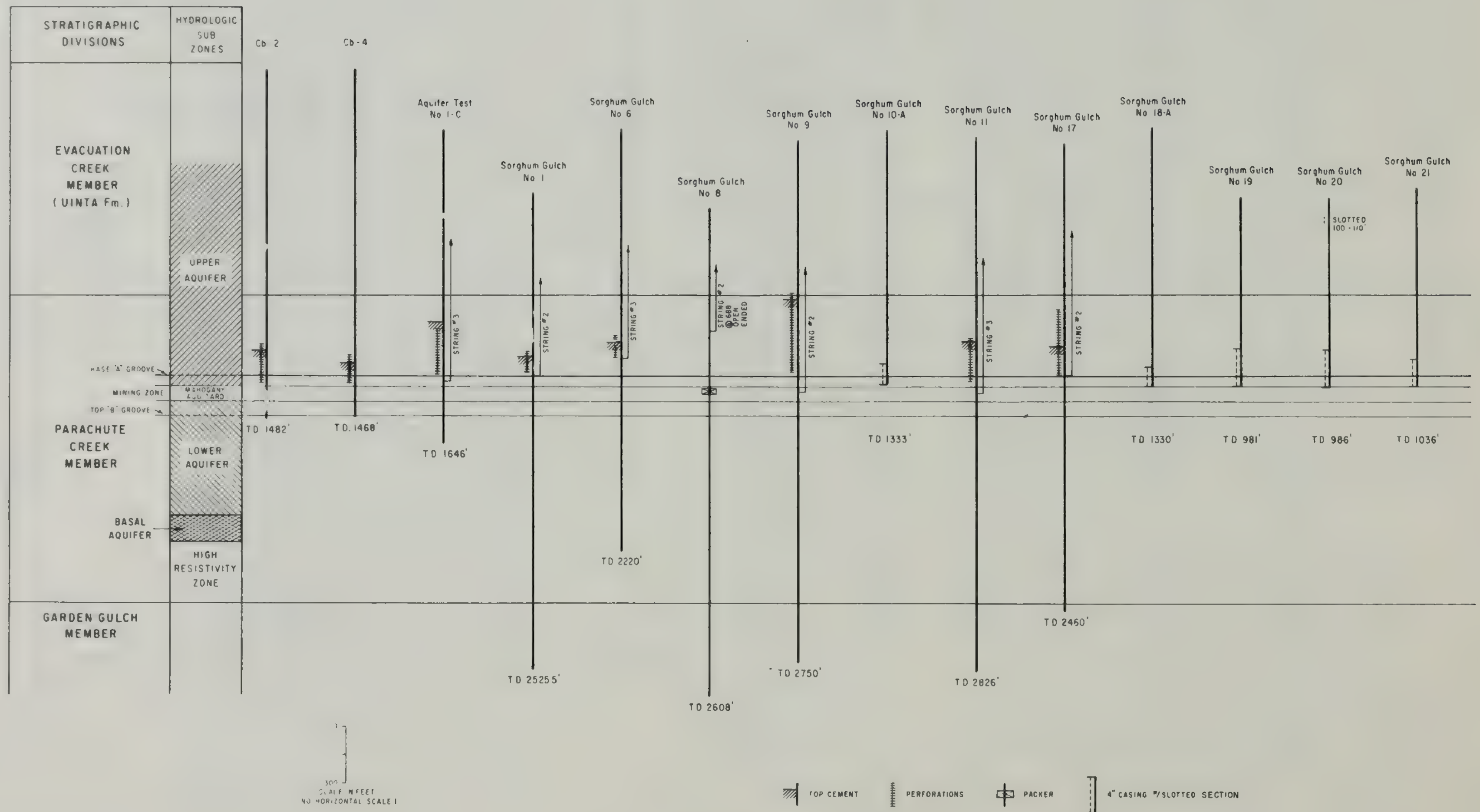


TABLE III-13

SUMMARY OF MONITORING WELLS

UPPER ZONE	LOWER ZONE	MAHOGANY VUGULAR (or Mining Zone)
AT 1a1		
	AT-1a*	AT-1a*
AT-1b		AT-1b
AT-1c	AT-1c	AT-1c
AT-1d		AT-1d
SG-1*	SG-1*	
		SG1a
SG-6*	SG-6*	SG-6*
SG-8*	SG-8*	
SG-9*	SG-9*	
	SG-10*	SG-10
SG-10a		
SG-11*	SG-11*	SG-11*
SG-17*	SG-17*	
SG-18a**		
SG-19*		
SG-20*		
SG-21*		
	Cb-1	
Cb-2		
Cb-4		
Alluvial Wells A1-A13 (A-4 dry; A-13 dry)		

*Core holes

**SG-18 was cored but later plugged and abandoned with drill collars in the hole. SG-18a was drilled as a twin; no cores were taken in 18a.

data is presented on Figure III-32. In general three major water-producing zones are present beneath the Tract: 1) the interval immediately below the Four Senators; 2) A Groove; and 3) B Groove. Zones (1) and (2) are in the upper aquifer and zone (3) is in the lower aquifer. In addition a minor water-producing zone of local extent occurs at the Uinta-Parachute Creek contact. Production for the entire interval was always less than 800 gallons per minute (GPM), the maximum rate that the water could be discharged during drilling.

Discharge generally increases as the well is deepened, but because water could flow out into unsaturated zones in the open hole, some wells occasionally show a decrease in discharge with increasing depth. No lateral or areal patterns in water production rates could be seen.

Jetting tests were also conducted as part of the drilling program on the Tract. During actual drilling operations, both discharge (water production) rates and electrical conductivities of the produced water were routinely recorded at approximately 30-foot intervals as part of the general well history. In addition drilling operations were periodically shut down so that jetting tests could be conducted. In a typical deep well, jetting tests were performed at the following stratigraphic horizons: 1) base of the Uinta formation; 2) top of the Mahogany zone; 3) base of the Mahogany zone; 4) top of the R-4 zone; and 5) total depth.

During each jetting test, air was blown down the drill pipe to the bottom of the hole to force the water to flow up and out of the hole. Discharge rates and continuous electrical conductivity of the produced water were recorded. After jetting was halted, measurements were made of the rate at which the water returned to the static level. Using the discharge data and water level recovery rates, the transmissivities of the various horizons were calculated, as summarized in Table III-14.

Again, because of open-hole conditions, these data must be considered only qualitative. Calculated transmissivities were highly variable, ranging from 1.34 to 1350 ft^2/day for the several wells drilled on Tract.

3. Drillstem Tests

Drillstem tests were conducted in three wells drilled on the Tract. The most comprehensive testing program was conducted in SG-17 where nearly 40 drillstem tests were run. Two drillstem tests were also run in each of the core holes SG-20 and SG-21.

In conducting each drillstem test, a packer was lowered on drill pipe to a predetermined depth. The packer was set (expanded) isolating the lower part at the hole. Water was jetted out of the drill pipe from the interval below the packer for a predetermined length of time. During jetting, discharge was measured and water samples collected. After the jetting was terminated, the rise or recovery in water level in the packed-off zone was recorded. Using discharge and recovery data, calculations were made of horizontal permeability.

Figure III-32. NORTH-SOUTH AND EAST-WEST STRATIGRAPHIC SECTIONS SHOWING WATER PRODUCTION CURVES.

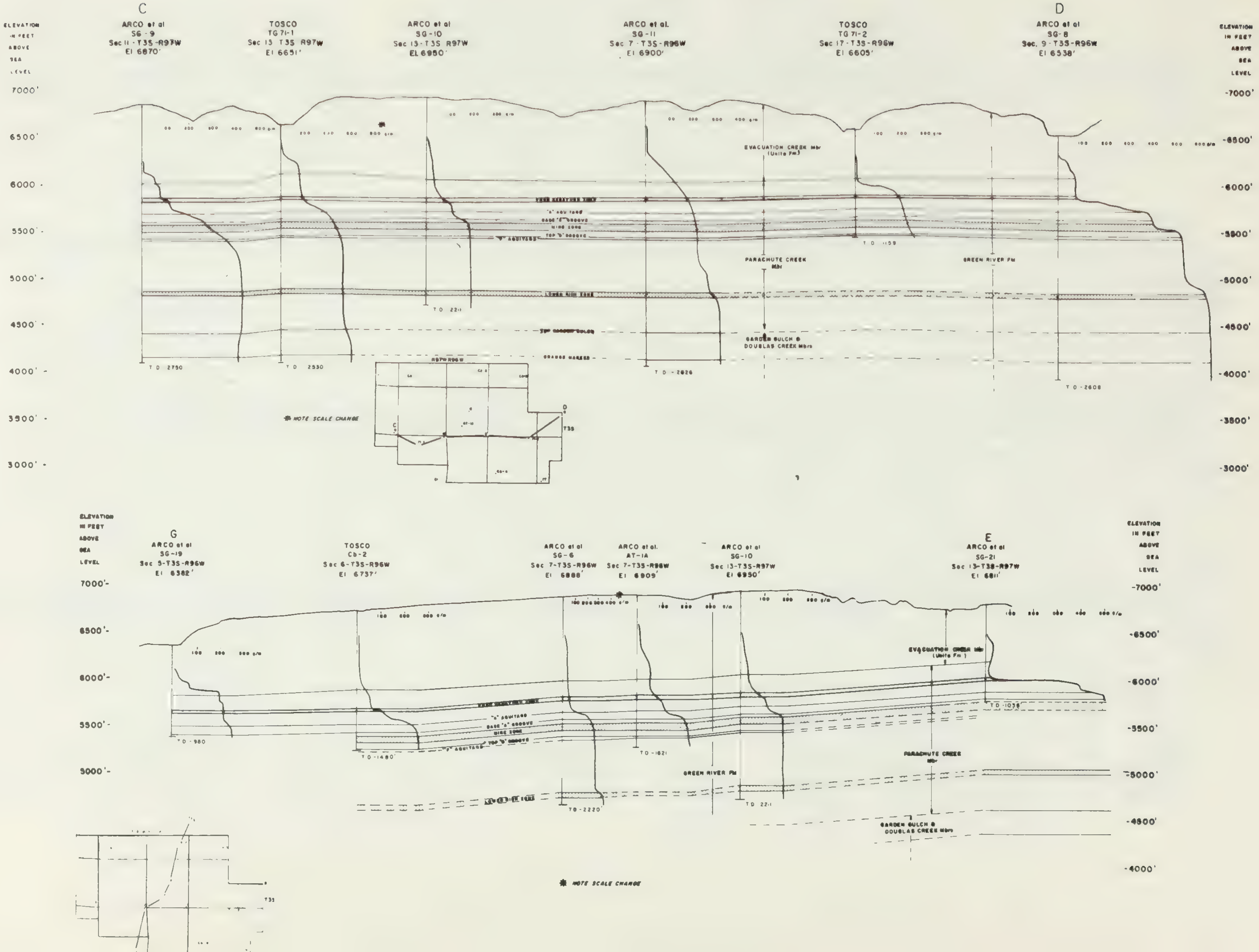


Table III-14 WELL DATA FROM JET TESTING

Well No.	Depth of Test	Transmissivity ft^2/day	Conductivity Micromhos	Production gal./min.
Cb-1	1280	134	1820	178
	1480	167	2000	–
	2100	195	3000	386
Cb-2	1280	668	2600	328
	1480	1203	2400	326
Cb-3	1240	869	2460	250
	1450	989	2400	300
	2122	1176	3040	350
Cb-4	1250	58.8	870	100
	1468	321	1010	230
SG-1	600	762	1000	610
	700	709	950	565
	1040	634	1000	467
	1105	820	1000	673
	2220	1158	2000	794
	2525	989	1900	840
SG-6	845	21.4	850	18
	1320	251	1250	189
	1440	330	1250	211
	1520	368	1300	211
	2220	439	1400	224
SG-8	600	334	1600	72
	970	540	1620	251
	1000	805	1600	251
	2115	1114	2400	494
	2608	1350	2600	458
SG-9	990	30.7	850	54
	1285	136	1200	282
	1360	179	1200	260
	2540	386	1100	274
	2750	310	1050	202
SG-10	960	23.5	–	21
	1330	398	850	148
	1430	402	900	167
	2211	1013	2100	152
SG-11	810	134	1180	112
	860	118	950	108
	1330	685	1005	176
	1390	566	1050	–
	1490	316	1200	108
	2465	752	2050	234
	2826	802	2250	148
SG-17	830	28.9	800	27
	1250	256	1400	103
	1330	284	–	153
	1622	271	1200	184
	2460	118	4400	162
SG-21	960	1.34	1100	11
	1036	660	600	292
TG-71-1	700	294	1140	200
	1040	802	9250	860
	2080	–	3300	–
	2150	–	1480	–
	2260	–	2800	–
	2300	–	3980	–
	2400	–	2500	–
	2530	450	2740	660
TG-71-2	630	–	760	–
	720	–	1100	–
	1000	628	–	–
	1162	615	–	–

The drillstem test has several important advantages over routine jetting tests:

a. It allows a direct calculation of horizontal permeability for a particular small interval in the hole.

b. It allows the collection of a water-quality sample from a small discrete subsurface interval.

c. It can be used to provide a permeability and water-quality profile of how conditions change with depth.

In addition to the standard, single-packer drillstem tests, more sophisticated multi-packer tests were also conducted during the drilling of SG-17. A three-packer tool was assembled in which water could be selectively injected into very small packed-off intervals. Twelve intervals were tested by this method. In all the tests water was injected into the primary packed-off interval at rates of 5, 10, 20 and 20+ gallons per minute. The change in pressures in the various zones was recorded. After completing the injections, the tool was loosened, raised to a higher interval and another test was run.

The principal objective of the multi-packer testing was to determine vertical permeability. The configuration of the tool and packer assembly permits the collection of pressure data which theoretically can be reduced to yield vertical permeability values.

Horizontal permeability values determined by drillstem tests and multi-packer tests are summarized in Table III-15. The test results indicate that vertical permeabilities, however, were too low to be accurately determined by this testing procedure. The evaluation was done by computer, using oil-field analytical techniques and the data were reported in millidarcies (md) rather than in usual hydrologic units. The greatest horizontal permeability is 300 md, the smallest was 1.6 md.

4. Pump Tests

To better define the aquifer characteristics, two series of pump tests were conducted, referred to as the main aquifer tests and the mini-pump tests.

The main aquifer test was designed to determine the hydraulic characteristics of the upper and lower aquifers beneath the Tract as defined by the USGS in its regional model of the basin. The main aquifer test area was located near the center of the Tract (Figure II-1). These tests can be described best as two separate tests. The first test consisted of a central pumping well surrounded by eight monitoring wells. The pumping well was completed in the upper aquifer. Monitoring wells were completed with multiple strings of tubing and packers which isolated the upper and lower aquifers in the observation wells. The producing well was pumped for 30 days, allowed to recover for 5 days,

Table III-15 SG-17 DRILLSTEM AND MULTI-PACKER TESTS

DRILLSTEM TESTS

DST No.	Interval, feet	Permeability, md.
1	386-436	N.D.
2	788-808	N.D.
3	822-869	11.0
4	866-919	12.7
5	919-970	34.0
6	967-1017	10.7
7	1017-1067	19.9
8	1066-1116	20.0
9	1116-1166	8.0
10	1164-1212	185.0
11	1200-1224	21.2
12	1215-1224	20.8
13	1224-1251	300.
14	1251-1271	8.0
15	1280-1309	13.0
16	1309-1336	N.D.
17	1327-1373	52.
18	1373-1419	15.
19	1423-1470	N.D.
20	1423-1470	23.9
21	1473-1522	3.0
22	1428-1522	4.7
23	1512-1572	4.0
24	1561-1572	23.0
24 (J)	1561-1622	N.D.
25	1618-1640	4.0
25 (J)	1618-1670	1.6
26	1668-1679	30.0
26 (J)	1668-1720	7.3
27	1711-1770	6.0
28	1768-1779	42.0
28 (J)	1768-1820	9.8
29	1818-1870	2.0
30	1869-1880	275.
30 (J)	1869-1910	30.
31	1918-1970	4.0
32	1966-2020	169.
33	2018-2070	N.D.
34	2120-2170	30.
35	2220-2270	N.D.
36A	2320-2370	N.D.
36B	2315-2370	N.D.
37	2395-2460	35.

(J) – Jetting Test

MULTI-PACKER TESTS

MPT No.	Interval, feet	Permeability md.
1	1089-1114	75
2	1123-1148	N.D.
3	1147-1172	92
4	1184-1209	N.D.
5	1338-1363	N.D.
6	1422-1447	N.D.

N.D. – No data obtained due to equipment malfunction, analytical problems, no water injection, packer leakage, etc.

pumped for an additional five days and finally allowed to recover for 30 days. Responses of the upper and lower aquifers in the observation wells were recorded. Discharge rates, water level measurements and water production rates of the pumping well were continuously recorded. Water samples were collected on a regular basis.

The second main aquifer test was identical in concept with the first, except that the pumping well was deepened and recompleted so that only the lower aquifer would be pumped. In this test the producing well was pumped for 18 days, allowed to recover for eight days, pumped for an additional eight days and finally allowed to recover for 20 days. Based on these data, computations have been made of transmissivity, storage coefficient and water production of the upper and lower aquifers. Vertical hydraulic conductivity of the Mahogany zone was also determined.

A series of short-term pump tests (called the mini-pump tests) were conducted on two wells (SG-1 and SG-1A), located about 100 feet apart in the northwest corner of the Tract (Figure II-1). The principal purpose of this test series was to determine the extent to which thin zones of rich oil shale act as aquitards and restrict vertical flow.

The mini-pump tests consisted of a pumping well (SG-1A) and an observation well (SG-1). By means of multiple-packer arrangements, the same aquifer unit was isolated in both the pumping and observation well. Recording devices were placed in the observation well to measure vertical flow through the aquitards into the isolated aquifer. Four intervals were tested using this procedure. The pumping periods lasted from 12 to 24 hours followed by recovery periods of 2 to 6 hours. The amount of water discharged by the pumping well was measured during the testing of each unit. From the information collected, computations were made of the vertical hydraulic conductivity of several aquitards. Transmissivities and storage coefficients of the four individual aquifer units were also determined. Water-quality samples were taken on a regular basis during testing and water electrical conductivity was recorded hourly.

The main aquifer tests were designed to obtain transmissivities and storage coefficients of the upper and lower aquifers and the leakance across the Mahogany zone. Data were analyzed using the equations for leaky artesian reservoirs from R. E. Glover's "Transient Groundwater Hydraulics" (1974). Results of the computations are summarized on Table III-16. Data from the upper main aquifer test have good consistency. Close-in wells exhibit very good curve-fits to the data. The more distant wells approximate the type-curve analysis reasonably well. Transmissivity of the upper aquifer ranges from 233 ft^2/day to 128 ft^2/day and arithmetically averages 168 ft^2/day. The storage coefficient in the upper aquifer averages 5.04×10^{-4} and varies from 1.68×10^{-3} to 6.92×10^{-5}. Vertical leakance ranged from 6.0×10^{-6} day^{-1} to 4.25×10^{-7} day^{-1}. The average discharge of the pumped well over the drawdown period was 373 GPM. During the upper test no drawdown was noted in the lower aquifer which establishes that no vertical leakage occurred through the Mahogany zone during this test.

Table III-16 RESULTS OF AQUIFER PUMP TESTS
UPPER AQUIFER

Well Number (String #)	Transmissivity ft^2/day	Storage Coefficient	Leakance day−1
SG–10	233	4.21×10^{-4}	4.26×10^{-7}
AT–1A(#3)	159	4.23×10^{-4}	6.10×10^{-6}
SG–6	212	1.68×10^{-3}	1.27×10^{-6}
AT–1D(#3)	130	2.97×10^{-4}	8.05×10^{-7}
AT–1B	162	3.71×10^{-4}	1.56×10^{-6}
AT–1C	128	2.73×10^{-4}	1.23×10^{-6}
SG–11	155	6.92×10^{-5}	5.90×10^{-7}
	LOWER AQUIFER		
AT–1C(#2)	20.4	1.22×10^{-4}	1.96×10^{-5}
AT–1C(#1)	40.9	1.21×10^{-5}	3.93×10^{-7}
AT–1D(#1)	35.4	2.67×10^{-5}	8.77×10^{-7}
SC–6(#1)	91.9	5.30×10^{-4}	
AT–1D(#1)	43.8	4.19×10^{-4}	
SG–6(#2)	35.7	6.48×10^{-5}	3.44×10^{-6}
SG–10(#10)	14.7	3.92×10^{-5}	6.88×10^{-6}

The anlayses of the lower main aquifer drawdown test also show a good fit of the observation well data to the type curves. The transmissivity ranges from 14.7 ft^2/day to 91.9 ft^2/day. The arithmetic average transmissivity is 40.4 ft^2/day. The storage coefficient is generally only half as large as in the upper aquifer with an average storage coefficient of 1.73×10^{-4}. Storage coefficients range from 5.3×10^{-4} to 1.21×10^{-5}. Computed leakance values are of the same order of magnitude as in the upper aquifer, ranging from 3.93×10^{-7} to 1.96×10^{-5} day^{-1}. The average yield of the well during this test was 120 GPM. Linear data plots show that no water moved vertically downward through the Mahogany zone during the pumping of the lower aquifer.

During both main aquifer tests significant anisotropic, nondirectional flow was noted. Well SG-11 was noted to drop much more rapidly than the two closer wells, SG-6 and SG-10. Computations analyzing the drawdown relationship, using R. E. Glover's equations for anisotropic analysis (unpublished equations being prepared for publication in 1976), derived a greatest-permeability direction for the upper aquifer as being in the east-northeast direction from the pumped well with a ratio of 9:1. Because of limited data, the analysis can only state in general that the direction of greatest permeability in the lower aquifer lies in a more north-south direction.

The mini-pump tests were mainly designed to determine the extent to which thin, rich, oil shale zones restrict vertical water flow. Using approximations of the aquitard thicknesses derived from geophysical logs, the computed leakance varies from 3.20×10^{-7} to 7.58×10^{-4} day^{-1}. The vertical, hydraulic conductivities, using estimated aquitard thicknesses, range from 3.06×10^{6} to 4.55×10^{3} ft/day. From these analyses and those of the main aquifer tests, it can be seen that leakance and actual vertical permeabilities are very small. The transmissivities obtained from the mini-pump tests are also small, ranging from 1.71 ft^2/day to 18.4 ft^2/day. The storage coefficient is in the same order of magnitude as the main aquifer tests previously discussed, ranging from 2.08×10^{4} to 1.20×10^{3}. Results of the individual aquifer tests are summarized on Table III-17.

5. Water Levels

Water-level measurements are taken once a month. Measurements are made with electronic sensing devices, steel tapes and continuous recording gauges. Representative examples of water level plots for the upper aquifer are given in Figure III-33. Those wells closest to the aquifer test pad showed a drop as a result of water withdrawal during the test, followed by a normal recovery curve which reached its peak in mid-year. All wells show a mid-year peak, followed by a decline which in some wells is very sharp. The decline reached a low in late summer to early fall and is followed by a recovery in all but 3 wells, SG-9 String #1, SG-1 String #1 and SG-18A. SG-9 and SG-1 are on the western side of the Tract and SG-18A is two miles south of the Tract. This area is apparently slower to recover than the rest of the Tract area. The second year's data should be more illuminating with respect to any long-term changes within the aquifer.

Table III-17 RESULTS OF MINI PUMP TESTS

Test Number	Transmissivity ft^2/day	Storage Coefficient	Leakance day−1	Vertical Hydraulic Conductivity ft/day
Test #4	1.71	2.08×10^{-4}	3.20×10^{-7}	3.06×10^{-6}
Test #6	5.27	9.13×10^{-4}	7.58×10^{-4}	4.55×10^{-3}
Test #8	18.4	4.34×10^{-4}	1.84×10^{-5}	3.06×10^{-6}
Test #10	11.6	1.20×10^{-3}	4.63×10^{-5}	2.78×10^{-4}

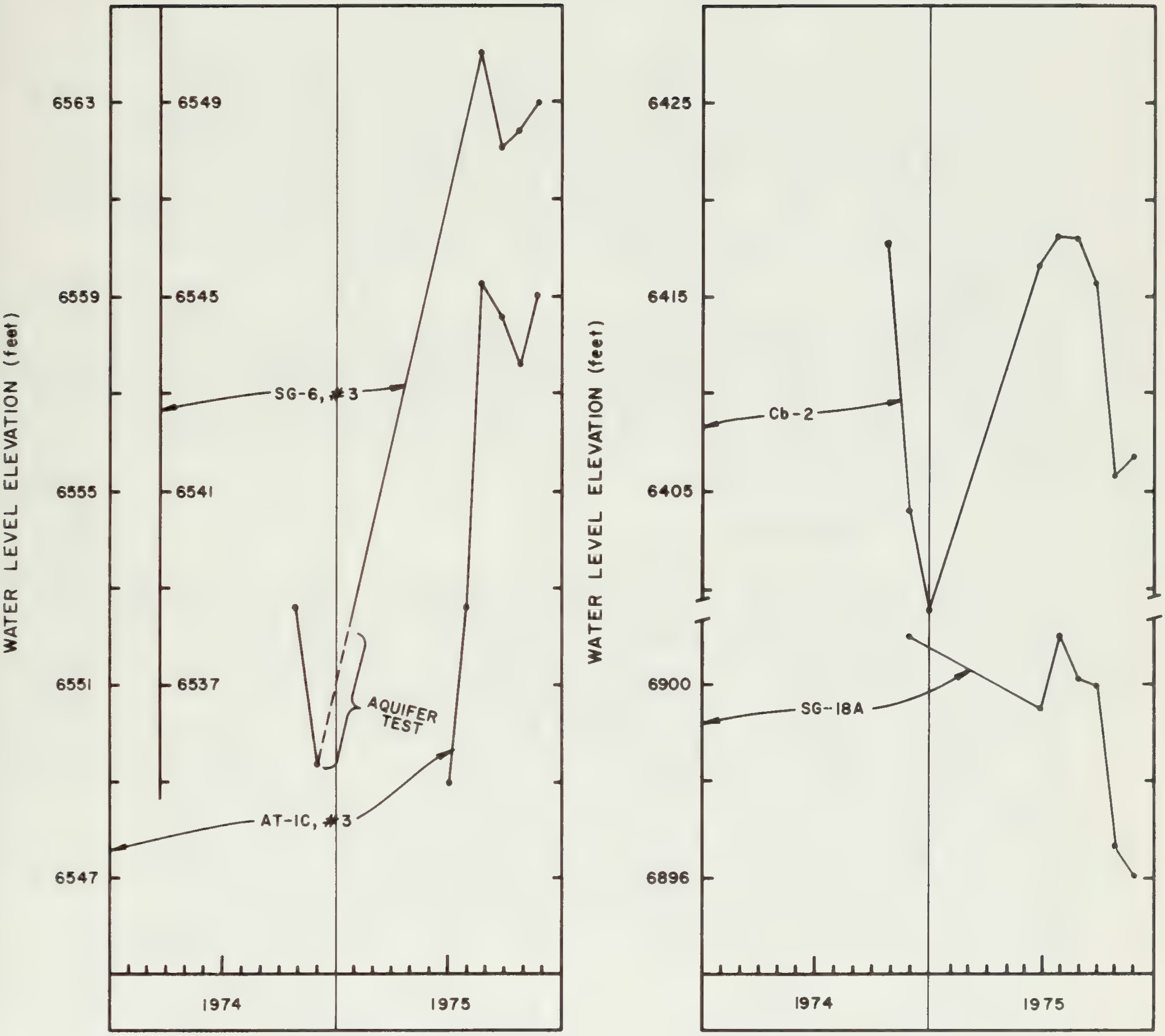


Figure III-33. WATER LEVEL DATA, UPPER AQUIFER

Lower aquifer wells close to the aquifer test pad have generally shown a continuous recovery through the year (See well AT-1C, #1, Figure III-34). However, outlying well SG-10 shows an almost continuous drawdown and other wells show various reversals in pattern (See well SG-11, #2 and SG-9, #1, in Figure III-34). The data are insufficient to support any firm conclusions regarding cycles or trends in water levels. It is possible that decreases noted in the fall in a number of wells are related to the swabbing done at that time to obtain water samples for chemical analysis.

Two potentiometric maps have been constructed for the upper and lower aquifers as defined by the USGS (Figures III-35 and III-36). These maps are based on water-level measurements from wells completed only in the individually mapped aquifers. The hydrostatic head difference between the two aquifers varies from a measured low of +5 feet in the northwest corner of the Tract (SG-1) to a high of +69 feet in the north-central part of the Tract (SG-6). Throughout the Tract, the upper aquifer always has a higher head than the lower aquifer.

The contour of the potentiometric surface of the upper and lower aquifers generally follows the same pattern as the regional structure. The surface slopes to the north with a gradient varying between 125 and 175 feet per mile. The uniform nature of the contours indicates that, in general, the hydraulic gradient is relatively uniform across the Tract. The main aquifer tests, however, demonstrated a strong anisotropic nature in flow to wells.

6. Water Quality

During the drilling of all the Tract wells records were maintained of the variation of water conductivities with depth. Some of these data have been plotted on cross-sections to illustrate both the vertical and horizontal variability of water conductivities. Figure III-37 shows two typical cross-sections. In general, the conductivity of the Uinta formation aquifer is between 1000 and 1800 micromhos (μmhos). The water of the Upper Parachute Creek member aquifer is indicated to be less saline than the Uinta Formation waters. It is usually less than 1200μmhos and commonly under 1000μmhos. Below the Mahogany zone the conductivity increases again but in this part of the section it generally remains less than 2000μmhos. Below the R-4 zone, a 50-foot zone of extremely high conductivity water was encountered which had a total dissolved solids content exceeding 30,000 mg/l. On the average, conductivities of water produced during drilling below the R-4 zone were greater than 4000 μmhos.

Although samples taken during drilling show some vertical variation in conductivity, samples taken at isolated zones from drillstem tests show much more dramatic differences in dissolved solids content. Figure III-38 graphically illustrates the total dissolved solids resulting from analyses of the drillstem tests on SG-17. The major zones of obvious chemical difference are: 1) the section above the Four Senators zone; 2) the interval between the Four Senators and the top of the

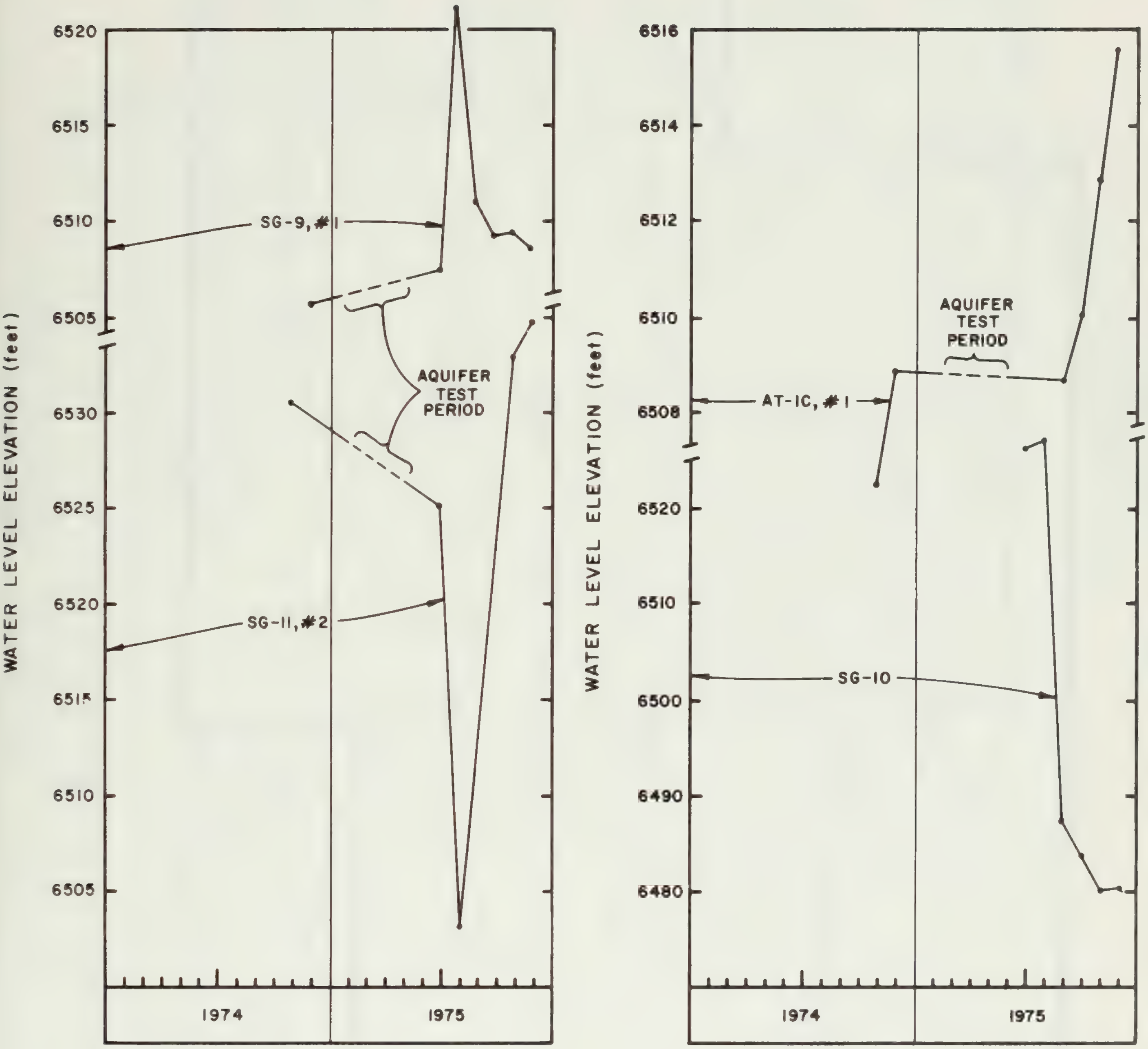


Figure III-34. WATER LEVEL DATA, LOWER AQUIFER

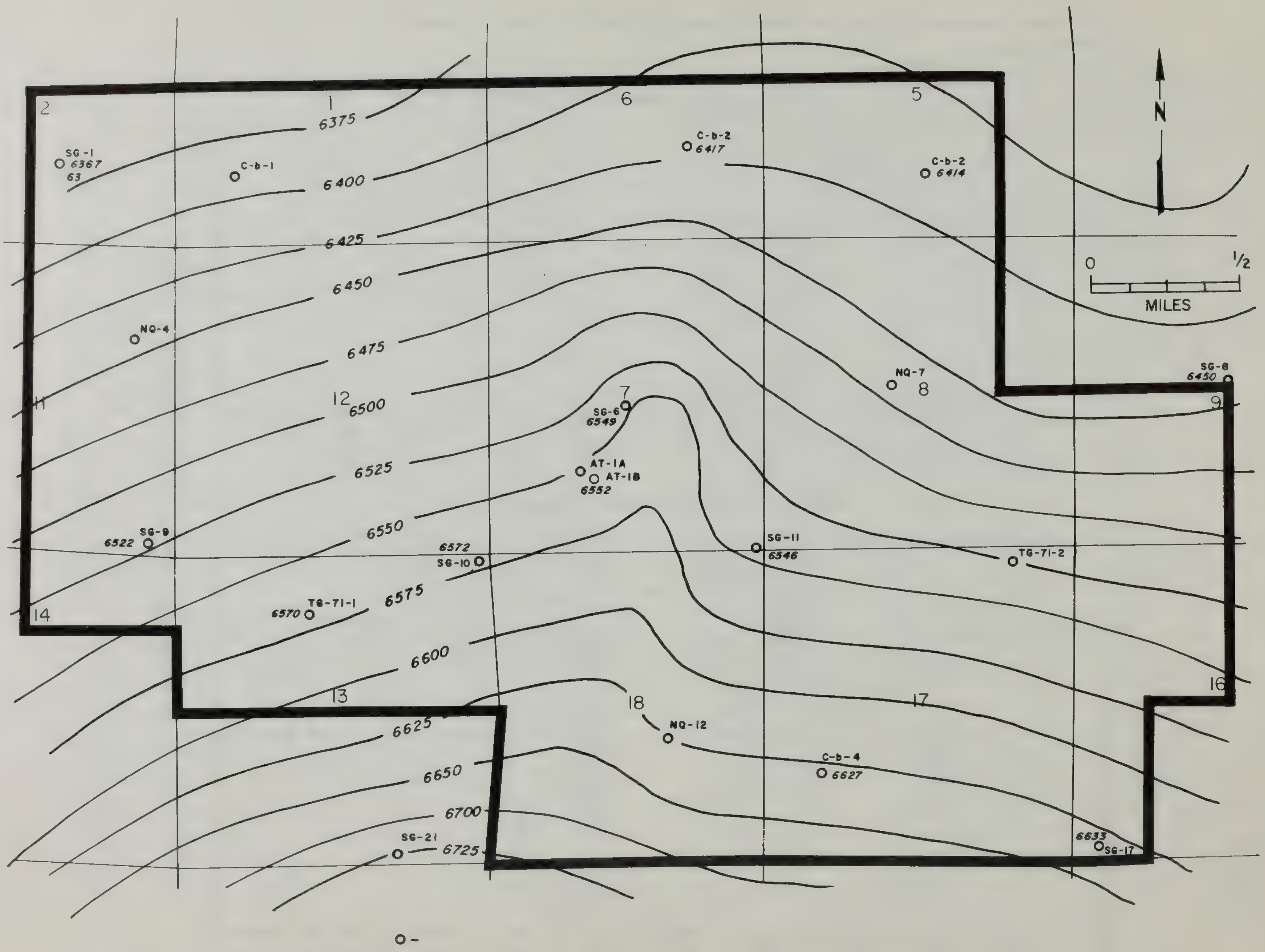


Figure III-35. POTENTIOMETRIC SURFACE - UPPER AQUIFER.

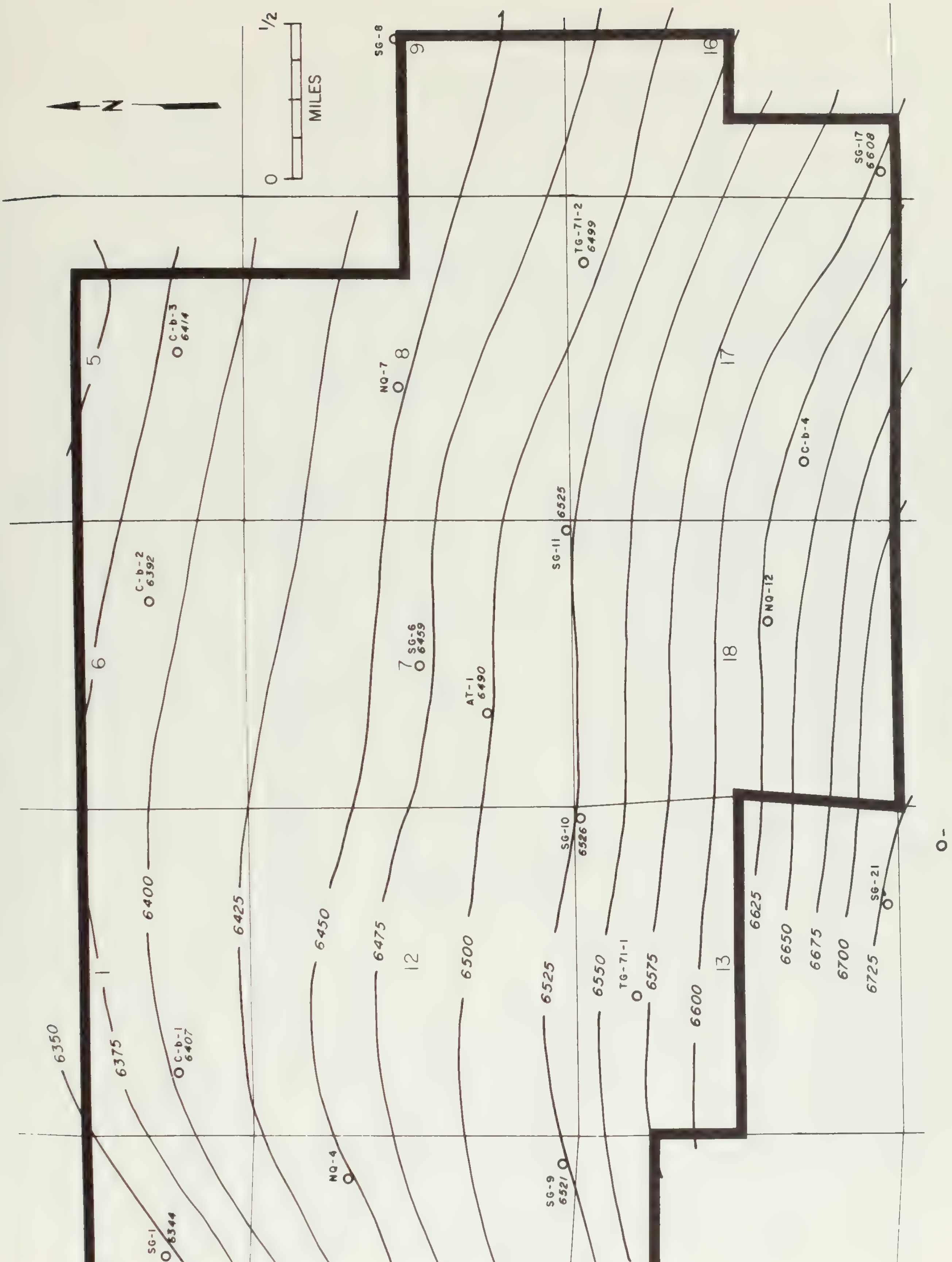


Figure III-36. POTENTIOMETRIC SURFACE - LOWER AQUIFER.

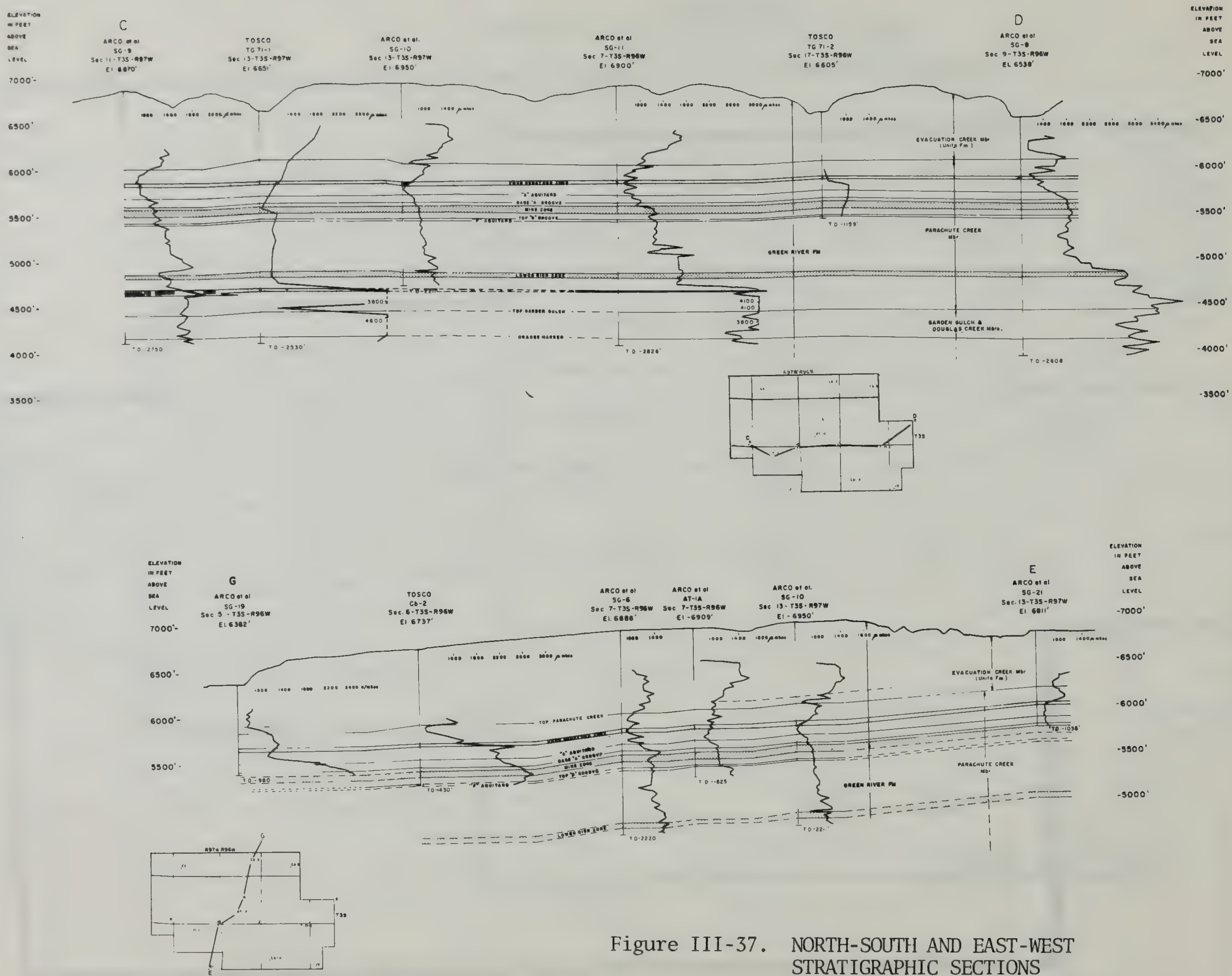


Figure III-37. NORTH-SOUTH AND EAST-WEST STRATIGRAPHIC SECTIONS SHOWING WATER CONDUCTANCE CURVES.

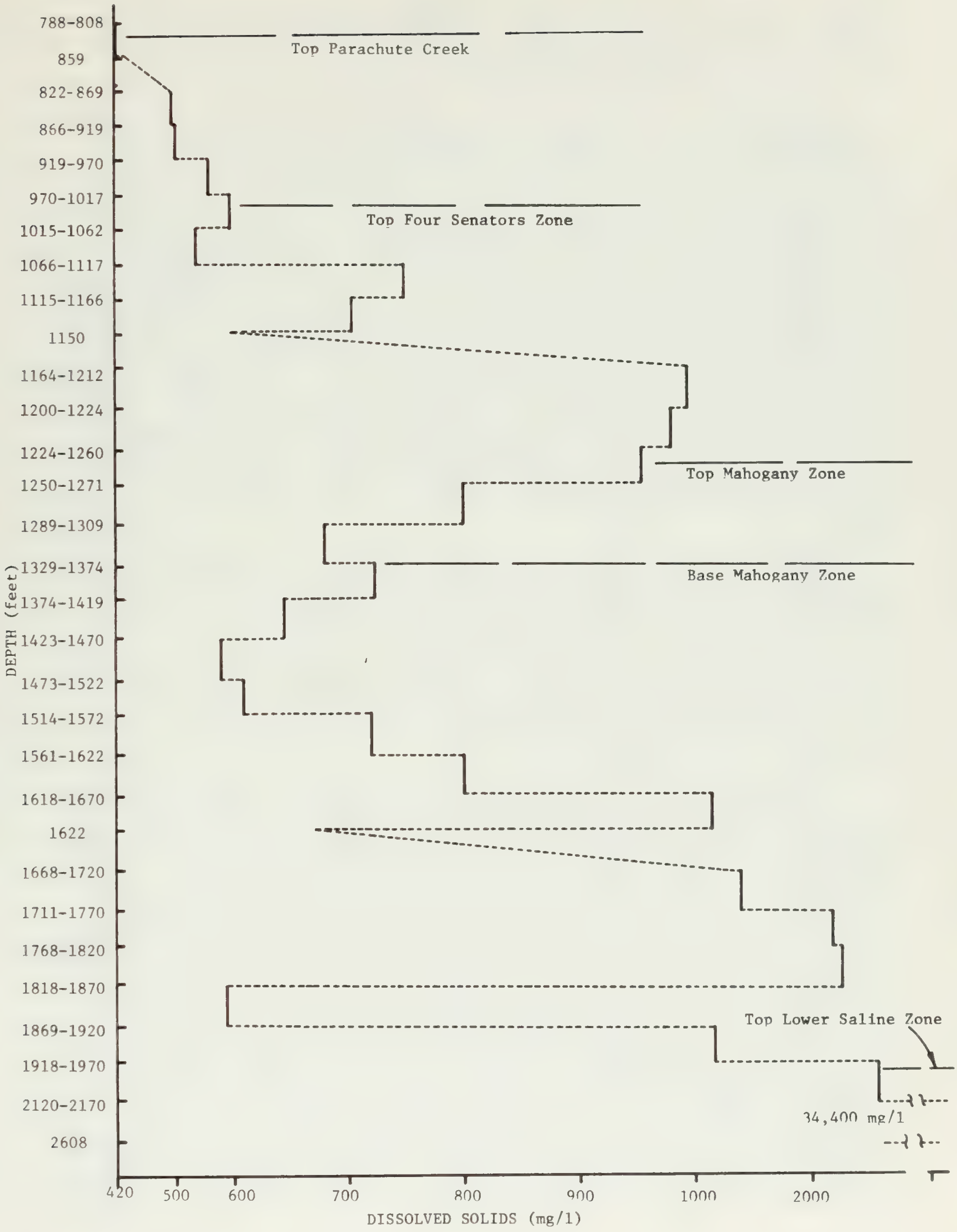


Figure III-38. TOTAL DISSOLVED SOLIDS FROM DRILLSTEM TESTS ON SG-17.

Mahogany zone; 3) the upper part of the lower aquifer; 4) the lower aquifer above the R-4 zone; and 5) the high saline zone below the R-4 zone. Within each major zone the dissolved solid content fluctuates over a range of several hundred mg/l.

Three water quality sampling runs have been completed at six-month intervals. Results are tabulated separately for the upper and lower aquifer wells in Tables III-18 and III-19, respectively. In general the variability of the data is much greater for the deep wells than for the springs and alluvial wells. The variability from well to well is attributed in large part to the highly stratified character of the formations beneath the Tract and the different intervals perforated in each tubing string. Additional well-to-well variability and some sample-to-sample variability for the same well may result from differences in the amount of water swabbed out (removed) during sampling. With a well open to several different strata containing water of different compositions, a composite sample from the well will be most heavily influenced by water from the zones exhibiting the highest production rates. During sampling each well was swabbed for approximately the same length of time but the amount of water produced was highly variable as shown in Table II B-1 (5th Quarterly Summary Report). Only four barrels total were produced from SG-6, String #1 compared to 860 barrels from SG-17, String #1.

Measurable quantities of a wide variety of trace elements are found in the deep wells. In general, iodine, molybdenum, strontium, rubidium, bromine, titanium and scandium are observed regularly in all samples from the deep wells and also from the springs and alluvial wells. Cesium and zirconium are observed somewhat less regularly in all sources. Uranium, thorium, antimony, silver, yttrium, germanium and gallium occur fairly often in the deep wells but almost never in alluvial wells or springs. Strontium is the only element of the entire group which regularly appears at levels of 1 ppm or more.

"Important" trace elements are those elements for which recognized Public Health and EPA standards have been written. Of this group, beryllium, cadmium, hexavalent chromium and selenium are not present in concentrations sufficiently above the minimum detectable levels to make continued monitoring of value. Given the high dissolved-solids levels in all C-b waters, it might be expected that some of the naturally occurring trace elements would exceed public health standards. Aluminum, arsenic, cobalt, nickel, vanadium and zinc are found only in concentrations well below their allowable levels of 5, 0.1, 0.05, 0.2, 0.1 and 5 mg/l, respectively. Copper, lead and mercury exhibit sporadic analyses above the allowable levels of 0.2, 0.05 and 0.002 mg/l, but in no case have the levels been consistently exceeded. Excessive barium levels (above 1.0) have been observed only in three wells in the lower aquifer, SG-10, 11 and 17. High boron concentrations (above 1.0 mg/l) are observed regularly in the deep wells and extremely high levels occur in some lower-aquifer wells. Allowable fluoride levels (1.0 mg/l) are exceeded almost universally by an order of magnitude in deep wells. Allowable iron and manganese concentrations are exceeded often in all water sources

TABLE III-18

SELECTED WATER QUALITY CONSTITUENTS
UPPER AQUIFER WELLS
Chemical Analyses in mg/1

	Maximum	Mean	Standard Deviation
Conductance	4200	1700	760
pH	9.1	8.6	0.24
Dissolved Solids	3100	1100	530
Hardness	720	230	200
Organic Carbon	9	2.9	2.4
Aluminum	4.0	0.49	0.85
Ammonia	7.9	1.1	1.3
Antimony	0.02		
Arsenic	0.06	0.014	0.012
Barium	0.6	0.10	0.12
Bicarbonate	2100	810	540
Boron	18	1.8	3.1
Bromine	0.2	0.036	0.043
Calcium	117	30	28
Carbonate	76	23	20
Cesium	0.2	0.016	0.038
Chloride	514	32	86
Cobalt	0.01	0.003	0.002
Fluoride		12	32
Gallium	0.003		
Germanium	0.002		
Iodine	0.08	0.008	0.014
Iron	1.3	0.27	0.34
Lead	0.07	0.013	0.01
Magnesium	150	40	39
Manganese	0.6	0.082	0.12
Mercury	0.0031	0.0006	0.0008
Molybdenum	0.1	0.027	0.023
Nickel	0.2	0.019	0.034
Nitrate	2.1	0.47	0.50
Potassium	11	2.6	2.5
Rubidium	0.05	0.016	0.012
Scandium	0.009		
Silica	32	17	6.2
Silver	0.05		
Sodium	1200	350	270
Strontium	17	2.4	2.9
Sulfate	520	200	155
Thorium	0.001		
Titanium	2	0.16	0.33
Uranium	0.03		
Vanadium	0.006	0.002	0.001
Yttrium	0.01		
Zinc	2.0	0.31	0.52
Zirconium	0.03		

TABLE III-19

SELECTED WATER QUALITY CONSTITUENTS
LOWER AQUIFER WELLS
Chemical Analyses in mg/1

	Maximum	Mean	Standard Deviation
Conductance	45,000	9900	15,000
pH	9.1	8.8	0.2
Dissolved Solids	42,000	8900	14,000
Hardness	310	78	56
Organic Carbon	40	10	11
Aluminum	1.0	0.27	0.25
Ammonia	197	27	55
Antimony	0.08	0.015	0.021
Arsenic	0.2	0.03	0.04
Barium	8	1.0	2.0
Bicarbonate	25,000	5600	8400
Boron	405	60	120
Bromine	10	1.2	2.7
Calcium	28	8	5.7
Carbonate	2000	350	610
Cesium	4	0.41	0.99
Chloride	9800	1900	3400
Cobalt	0.03	0.006	0.008
Fluoride	48	23	11
Gallium	0.02		
Germanium	0.05		
Iodine	3	0.46	0.87
Iron	7.9	0.99	2.0
Lead	0.4	0.034	0.073
Lithium	79	15	28
Magnesium	29	8	5.7
Manganese	0.3	0.086	0.067
Mercury	0.0027	0.0006	0.0008
Molybdenum	0.2	0.057	0.044
Nickel	0.06	0.012	0.014
Nitrate	3.4	0.7	0.9
Potassium	125	31	45
Rubidium	0.9	0.10	0.19
Scandium	0.01		
Silica	38	14	7.5
Silver	0.02		
Sodium	17,000	3700	5900
Strontium	6	1.3	1.4
Sulfate	350	56	76
Thorium	0.001		
Titanium	1	0.12	0.19
Uranium	0.02		
Vanadium	0.1	0.013	0.027
Yttrium	0.03		
Zinc	4	0.29	0.78
Zirconium	0.9	0.165	0.25

but by widely varying margins which are seldom consistent. This indicates that analytical methods may be at fault for these two elements.

Table III-20 lists the average values for important trace elements in the upper aquifer. For comparison the recommended maximum values for various uses ("Proposed Criteria for Water Quality," EPA, 1973) are also listed in the table. To summarize the analytical results for trace elements in the upper aquifer, only fluoride is clearly and consistently present at levels much too high for public or agricultural use. Boron, iron and manganese are present in concentrations near the maximum allowable. Barium, copper, lead and mercury exhibit occasional high values.

A generally accepted relationship in the Piceance Basin is that TDS equals 0.65 times conductance. Data for the upper aquifer indicates a factor of 0.67, which is in good agreement with the expected correlation. This correlation does not hold well in the lower aquifer for the very high levels of TDS and conductance.

Values for chemical parameters in the lower aquifer exhibit a wide variance because of the extremely high levels of dissolved solids found in some wells penetrating below the R-4 zone. For this reason, average values of parameters in the lower aquifer are not particularly meaningful. If only those wells terminating above the R-4 zone are considered, then the water below the Mahogany zone does not seem to be greatly different from that just above. It can be concluded that the ground water encountered above the R-4 zone on the Tract could be made acceptable for most uses if the excessive fluoride were removed.

F. Interpretations

1. Data Quality

Water quality data should usually be presented with no more than two, and often no more than one significant figure. This is just another way of saying that the accuracy of the data is seldom better than ten percent. Data variability about a true mean value arises from two basic sources: 1) errors or uncertainties in the laboratory analysis and 2) inability of the sampling procedure to obtain an adequately representative sample.

There are many possible sources of laboratory error. For example, discrepancies can occur because samples (particularly ground water samples) are not analyzed immediately after sampling in the field. Some constituents such as calcium, sulfate and bicarbonate tend to precipitate from solution on standing or exposure to air. Substantial changes in pH may result from shifts in various chemical equilbria because of evolution of gases or reaction with air. The use of different analytical techniques may produce a bias in the data. For example, titrations done with chemical indicators may be based on endpoints at pH 8.0 and 4.0 whereas electrometric titrations change at pH 8.2 and 4.0. Other types of difficulties may be illustrated in the analysis of salts, such as boron by spark source spectrometry. In this method there is a tendency to

TABLE III-20

IMPORTANT TRACE ELEMENTS IN GROUND WATER (UPPER AQUIFER)
ALL VALUES IN mg/l

Constituent	Mean Value Observed in Upper Aquifer	Recommended Maximum Values ("Proposed Criteria for Water Quality" – EPA, 1973)			
		Agriculture (Irrigation)	Agriculture (Irrigation-20 years)	Agriculture (Livestock)	Freshwater (Public Supply)
Aluminum	0.5	5.0	20	5.0	--
Arsenic	0.01	0.1	2.0	0.2	0.1
Barium	0.1	--	--	--	1.0
Beryllium	0.001	0.1	0.5	--	--
Boron	1.8	0.75 to 2.0	--	5.0	1.0
Cadmium	.002	0.01	0.05	0.05	0.01
Chromium	< 0.01	0.1	1.0	1.0	0.05
Cobalt	0.003	0.05	5.0	1.0	--
Copper	0.1	0.2	5.0	0.5	1.0
Fluorine	12	2.0	15.0	2.0	--
Iron	0.27	5.0	20.0	--	0.3
Lead	0.01	5.0	10.0	0.1	0.05
Manganese	0.08	0.2	10.0	--	0.05
Mercury	< .001	--	--	1.0	0.002
Nickel	0.02	0.2	2.0	--	--
Selenium	0.005	0.02	--	0.05	0.01
Vanadium	0.002	--	--	0.1	--
Zinc	0.3	--	--	25	5

consume the salts in the spark, so that readings are too low. Problems of interference may occur in highly saline samples. In short, every analytical procedure carries its own inherent limitations in accuracy. In addition, there are the "human" errors because of improperly operated equipment, poor calibrations and errors in arithmetic.

Many of the possible sources of laboratory error can be neutralized by sending duplicate samples to different laboratories for analysis. Most of the major constituents in the ground water samples were analyzed by Industrial Laboratories and also by The Oil Shale Corporation. Table III-21 lists the average percent difference in the values reported by the two laboratories for the alluvial well samples taken in the fall, 1975 sampling run. It can be seen that the average difference for all values is on the order of 20 percent, which is not unexpectedly large. The larger percent differences generally occur with the constituents present in smaller quantities, such that the analytical accuracy approaches the mean values of the concentrations. The calculated total dissolved solids values agree very well.

Chemical analysis of samples which are collected in the field is often subject to errors from contamination. Spurious results from contaminated samples can easily give misleading results. One way of statistically checking for this type of error is to compare the mean for a series of analyses against the median. In a normally distributed population of values, subject only to random errors, the calculated mean and median should be approximately equal. Referring to Table III-11 for the springs and seeps, those data which are least subject to contamination error and which show good accuracy in the inter-laboratory comparison, such as conductance, pH and total dissolved solids, will exhibit nearly identical values for the mean and median. On the other hand, iron, which is so closely associated with man and provides innumerable opportunities for contamination, exhibits a mean ten times greater than the median. This suggests that the mean has been influenced by a few very high values. In such a case the median may provide a much better indication of the true value than will the mean.

When considering both the susceptibility to influence by external factors and the time scale of movement, one might expect conditions in the lower aquifer to be the most stable and least subject to change. Next in order of changeability would be the upper aquifer, followed by the alluvial wells, the springs and finally by the streams. However, the complexities of the subsurface geology and the difficulty of obtaining an "average" sample increase with depth causing the variability of results to increase with depth, contrary to what might have been expected at first glance. Thus, in the lower aquifer the standard deviation from the mean (Table III-19) is, on the average, 150 percent of the mean value. Since values of concentration cannot be negative, a standard deviation greater than the mean indicates a highly non-normal distribution. For the upper aquifer (Table III-18) the average standard deviation is only 120 percent of the mean. For the alluvial wells it is 106 percent of the mean and for the springs the standard deviation is 70 percent of the mean. All of these samples were collected by the same

Table III-21

INTER-LABORATORY COMPARISON, FALL, 1975
ALLUVIAL WELL SAMPLES

Component	Average Percent Difference
Sodium	12
Potassium	47
Calcium	17
Magnesium	12
Sulfate	6
Carbonate	63
Bicarbonate	7
Chloride	29
Fluoride	16
Borate	36
Silica	29
pH	3
Total Dissolved Solids	3

personnel and analyzed by the same laboratories. These results show clearly that the problems of obtaining repeatable and representative samples far outweigh the variabilities in laboratory procedures.

In summary, chemical water quality data for individual constituents should not be presumed accurate to more than one significant figure. Firm conclusions should not be drawn on comparisons between two sources which vary by less than 20 percent.

2. Water Relationships

A question of major environmental concern is the effect which an oil shale mine would have on the flow of nearby springs and seeps. To attempt to answer this question, it is desirable to establish the relationships between stream and spring flows, alluvial aquifer levels, deep aquifer levels, yearly precipitation and other hydrologic factors. Additional data are required before these relationships can be adequately quantified.

In contrast to certain other springs in the Piceance Basin, none of the springs studied near C-b show obvious evidence of direct connections to the deep aquifers. Chemical analyses of samples from the springs and from alluvial wells are all consistent and almost identical in all respects. However, clearcut differences in ionic ratios are seen in the deep aquifers.

Calcium, magnesium, nitrate and sulfate are higher in the springs and alluvial wells than in the deep wells, but the opposite is true for bicarbonate, carbonate, chloride and sodium. Ammonia and potassium are high only in the lower aquifer. The pH values are similar for all sources, apparently increasing somewhat with depth. Because of the differences in ionic ratios discussed earlier, water in the springs and in the alluvial wells exhibits a significantly greater hardness than that in the deep wells. Radiation and organic carbon content reach significant levels only in the lower aquifer.

Alluvial water levels have not yet been adequately correlated with either precipitation or spring flows. Water level fluctuations in the deep aquifers are even less clearly related to the surface hydrological systems.

3. Dewatering Effects

Analyses of the tests conducted on the Tract to date have served to establish a better definition of the Tract geohydrology. The resulting aquifer model varies from the USGS regional model. The principal points of difference are: 1) the degree of vertical communication both between and within the major aquifers; 2) the measured transmissivities; and 3) the measured storage coefficients.

These tests have established the presence of two major zones of low permeability. The Four Senators zone and the Mahogany zone both restrict

vertical flow, as evidenced by distinct differences in water chemistry and direct leakance measurements. As a result, it is possible to define three major bedrock aquifers beneath the Tract. These are: 1) the Uinta Formation and upper Parachute Creek member above the Four Senators zone; 2) the upper Parachute Creek member below the Four Senators zone; and 3) the lower Parachute Creek member between the Mahogany zone and R-4 zone. The high salinity zone and the Douglas Creek-Garden Gulch system are considered to be separate minor aquifers.

In addition to the two major aquitards, thin, rich, oil-shale layers within the main, oil-shale zones further inhibit vertical movement of water. The main aquifer and mini-pump tests results indicate that vertical leakance in the upper and lower aquifers is one to two orders of magnitude smaller than USGS regional values.

A comparison of C-b data with the USGS report shows that both transmissivities and storage coefficients of the aquifer systems on the Tract are considerably smaller than those used by USGS to represent the basin. Transmissivity values for the upper aquifer system beneath the Tract range from 155 to 233 ft^2/day, while USGS values in the area range from 60 to 870 ft^2/day. The lower aquifer system on the Tract was found to have transmissivities approximately one-half those determined by the USGS for the area.

Based on the information derived from the hydrologic testing program, it appears that mine dewatering will be a considerably smaller problem than originally anticipated. Because the rock was found to have smaller transmissivities and storage coefficients than predicted, less water will infiltrate into the mine area than initially projected. Moreover, it appears that a limited stratigraphic interval adjacent to the mine zone can be successfully dewatered without disturbing the overlying and underlying aquifers. This means that if shafts and wells are properly sealed, the dewatering operation will have little effect on springs and seeps in the vicinity of the Tract.

Preliminary computer modeling results indicate a peak inflow of only 3.7 ft^3/sec for the mine shaft and development mine. Additional modeling of the mine dewatering requirements will be undertaken as further information becomes available.

IV. AIR QUALITY

A. Program Description

The Tract air-quality and meteorology programs meet environmental Lease Stipulations and are designed to satisfy the following objectives:

- establish the air-quality and meteorological baseline;
- become an integral part of the long term monitoring program and establish the basis for that program and aid in determining its scope, objectives and design;
- provide data that will allow a valid assessment and prediction of potential air-quality impacts and establish a basis for mitigating these impacts;
- provide environmentally oriented criteria for shale-oil plant design and location, such as peak wind speeds and the presence of temperature inversions.

The air-quality-meteorology monitoring network is shown in Figure IV-1. It consists of: 1) five air-quality stations (housed in trailers) for determining ambient levels of gaseous and particulate constituents and reporting the supporting meteorological data; 2) three mechanical weather stations for measurement of surface winds and temperatures; 3) a 200-foot meteorological tower to determine low-altitude vertical profiles of wind, temperature and relative humidity; 4) two acoustic sounders for measuring atmospheric inversions; and 5) one location for measuring area-wide visibility. The five air quality stations are:

Station No.	Description
020	Downwind of the proposed plant site in Piceance Creek Valley at the Redd Ranch (off-tract)
021	In Piceance Creek Valley at Rock School, downstream and generally downwind of Station 020 (off-tract)
022	In Piceance Creek Valley at the Gerald Oldland Ranch, upstream and generally upwind of Station 020 (off-tract)
023	On the Tract near the proposed plant site which is the present location of a 200-foot meteorological tower.

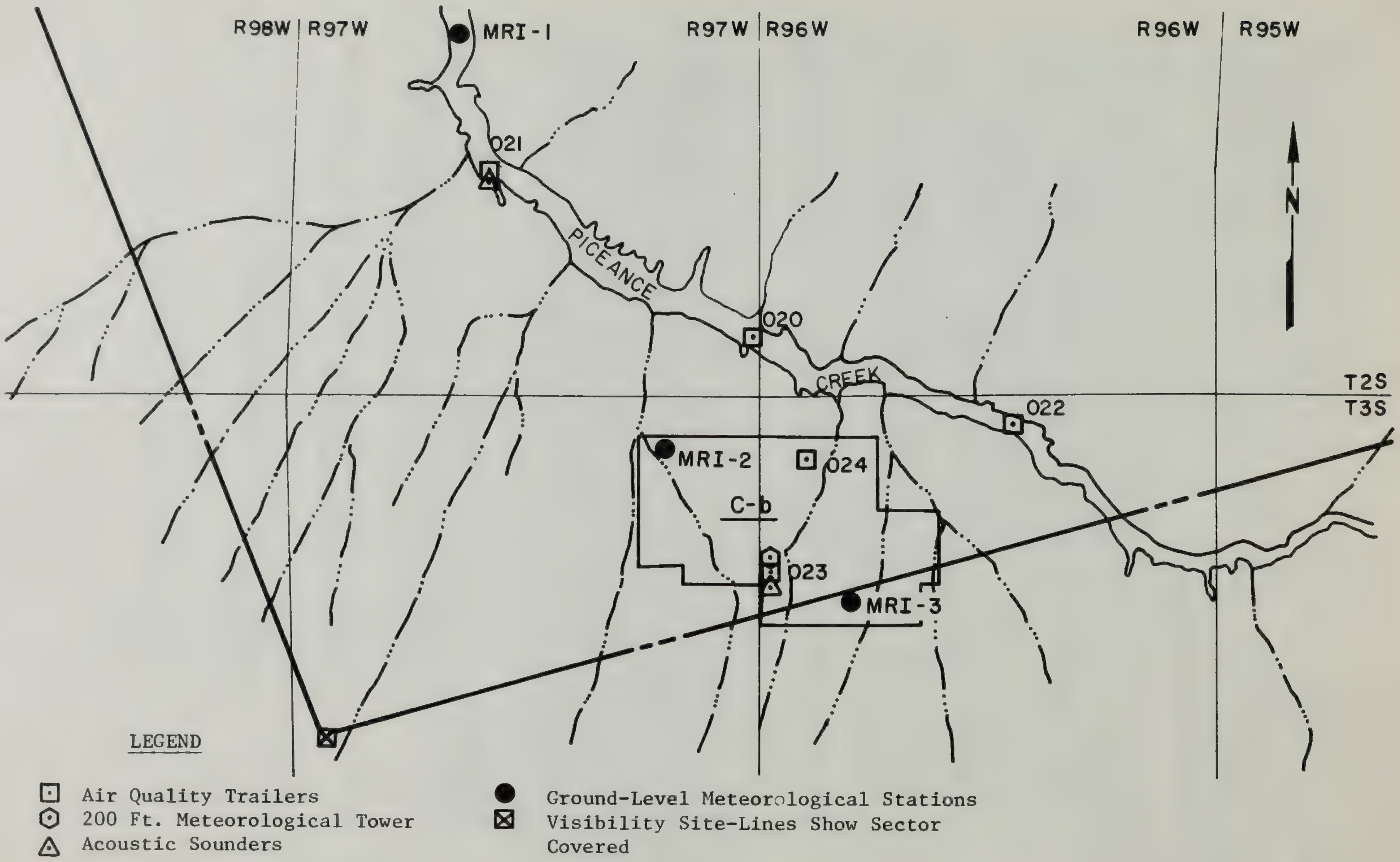


Figure IV-1 **AIR QUALITY AND METEOROLOGICAL STATION LOCATIONS**

024 On the Tract near a predicted point of estimated maximum concentrations downwind of the proposed plant site.

The prevailing winds from the south and southwest were used to help determine the location of Station 024 downwind of the proposed plant site. The location of the predicted point of estimated maximum concentrations is not precise since it ultimately will depend on actual plant stack characteristics, wind conditions and atmospheric stability. A diffusion model will be used to help predict the point more accurately.

The topography of the Piceance Creek valley usually constrains the air mass within the valley resulting in the formation of upslope (or upstream) flow of air during the day and downslope (or downstream) flow of air at night. This upstream and downstream flow is monitored by Stations 020, 021 and 022. Turbulence, caused by the roughness of the topography, and solar radiation are two other parameters affecting winds but these effects are more difficult to predict. Meteorological data taken at the five trailers and three weather stations create a better understanding of the complex wind patterns near the surface.

A detailed description of the air-quality and meteorology program, including the parameters measured and sampling frequencies, is presented in Tables IV-1 and IV-2. Sulfur dioxide, hydrogen sulfide and suspended particulates are monitored at all air-quality stations. In addition total hydrocarbons, methane, oxides of nitrogen, ozone and carbon monoxide are monitored at Stations 020 and 023. Wind speed and direction are measured at a 30-foot level at each station. Relative humidity, temperature and precipitation are also measured at each station; barometric pressure is measured at two stations and solar radiation at one station. In addition three mechanical weather stations provide wind speed, wind direction and temperature at hourly intervals. These are at the auxiliary locations shown on Figure IV-1.

The complex, near-surface, wind patterns vary with elevation above the surface. To assess this vertical variation, a 200-foot meteorological tower has been installed at Station 023, as shown in Figure IV-1. As indicated in Table IV-1, low altitude meteorological data are obtained on the meteorological tower at four levels (at 8, 30, 100 and 200 feet). These data consist of wind direction and speed, relative humidity and temperature. Temperature differences are obtained between the 100 foot and the 30-foot levels and between the 200-foot and the 30-foot levels to assist in determination of atmospheric stability. Bivane wind speed and horizontal and vertical components of direction are measured at the 30-foot, 100-foot and 200-foot levels.

Upper air studies were conducted to obtain vertical profiles of wind and temperature near the meteorological tower up to approximately 6000 feet above the surface. Wind data are obtained from pilot balloon (pibal) releases at the meteorological tower. Vertical temperature profiles are obtained by an instrumented aircraft flying in ascending and descending spirals. A knowledge of the variation in the temperature

Table IV-1 AIR QUALITY & METEOROLOGY DATA DESCRIPTION

Symbols represent sampling frequency on next table

Category & Location \ Measurement	SO_2	H_2S	Particulates	Total Hydrocarbons	Methane (CH_4)	Non-CH_4 H.C.(1)	Ozone	NO_x	NO	NO_2(2)	CO	Horizontal Wind Speed	Horizontal(3) Wind Direction	Bivane Wind Speed	Bivane Horizontal(3) Wind Direction	Bivane Vertical(3) Wind Direction	Relative Humidity	Air Temperature	Precipitation	Barometric Pressure	Solar Radiation	Temperature Difference	Acoustic Echo	Visibility
Air Quality & Surface Meteorology																								
Trailer 020	X	X	0	Y	Y	Y	X	X	X	X	Y	X	X				X	X	X					
021	X	X	0									X	X				X	X	X					
022	X	X	0									X	X				X	X	X					
023	X	X	0	Y	Y	Y	X	X	X	X	Y	X	X				X	X	X	X	X			
024	X	X	0									X	X				X	X	X	X				
Mechanical Weather Station																								
MRI 1												Z	Z					Z						
2												Z	Z					Z						
3												Z	Z					Z						
Low Altitude Meteorology																								
@ Met. Tower Ground Level																								
8 - Ft.												X	X				X	X						
30 - Ft.												X	X	X	X	X	X	X				1,2		
100 - Ft.												X	X	X	X	X	X	X				1		
200 - Ft.												X	X	X	X	X	X	X				2		
Upper Air Studies																								
@ Met. Tower 200 - 6000 Ft.												*	*					*						
Temperature Inversions																								
@ Met. Tower																							-m-	
@ Trailer 021																							-m-	
Visibility																								
@ Hunter Creek																								#

(1)Obtained by Subtraction: THC - CH_4

(2)Obtained by Subtraction: NO_x - NO

(3)Std. deviation is calculated here also

Table IV-2 AIR QUALITY & METEOROLOGY SAMPLING FREQUENCY & MIN. AVERAGING TIMES

Symbols appear on previous table

Symbol	Sampling Frequency	Min. Average Time or Report Frequency	Description
X	1/sec	5 min. average	AQ & low alt. met.
Y	5 min. average	5 min. average	
Z	Continuous	Hourly average	
0(1)	1/24 hr. span	(1) Daily Every 6th day Quarterly Quarterly Quarterly	(1) Particulates Trace elem. composites Gross radioactivity Part. size distribution Volatile metals
1	1/sec	5 min. average	Temp. difference between 30' and 100' height on met. tower
2	1/sec	5 min. average	Temp. difference between 30' and 200' height on met. tower
*	at least 2/day for 15 days/ quarter	same	High alt. meteorology temp. and wind profiles to 6000 ft.
ξ	1/(14-sec)	Onset & Extent of Inversions	Acoustic echo (for Temp. Inversions)
#	7 times per day every 6th day	same	Area-wide visibility via photographic photometry

(1) Particulate samples of 24-hour duration are obtained from Hi-Vol samples utilizing fiberglass filters. Every sixth day a 24-hour particulate sample on a cellulose filter is obtained. The quarterly composites of these filters are screened for trace elements and radioactivity. In addition, volatile trace metals are collected and analyzed by special techniques.

(T) with increasing altitudes (h) (called the lapse rate) helps in determining the atmospheric stability. If the actual lapse rate (dT/dh) is less negative than the dry adiabatic lapse rate (DALR), then the atmosphere is said to be stable and the vertical diffusion of gaseous constituents is inhibited. If the actual lapse rate is more negative than the DALR, then the atmosphere is said to be unstable and diffusion proceeds freely in both the horizontal and vertical directions. When the atmospheric air temperature increases with height, an inversion is said to be present.

Two acoustic sounders have been installed both on the Tract (at the meteorological tower) and in Piceance Creek valley (at Station 021). These sounders measure inversion heights continuously by emitting an audio pulse every 14 seconds and measuring the time for a return echo. If pronounced layers of either stable or unstable air exist, the pulse bounces off the layers. The time of travel is used to compute the height to the top of the layer. The specific "signature" (recorded pattern) indicates stability or instability.

A joint visibility study with the Rio Blanco Oil Shale Project (Tract C-a) was started in October, 1975. The visual-range in miles is measured every sixth day during a one-year period at the Hunter Creek ridge site, a point about midway between Tracts C-a and C-b (See Figure IV-1). Each measurement includes photographs of designated objects in each of four viewing directions covering an approximate 90^o north-to-east sector. Each view is photographed at specified times during the day with both black and white and color film. The contrast between the object image and the background sky, as determined from the film negative, is used to compute the visual-range in miles.

B. Data Quality

1. Radian Data

The Radian Corporation has a detailed, quality control program for air-quality monitoring in the five trailers on the C-b Tract. This program includes the following features:

a. All stations are visited daily by a trained operator.

b. A full-time, factory trained, instrument engineer monitors the system to maintain efficient operation.

c. All calibration sources except ozone are National-Bureau-of-Standards traceable.

d. All flows and dilutions in calibration units are measured and recalculated at least quarterly.

e. Detailed logbooks are maintained in each station.

f. A detailed checklist is completed daily at each station.

g. Each station features a computer for real-time, data processing. This is printed in the station on hardcopy and is inspected daily by the operator. In addition the computer performs certain checks on the data and signifies problems (e.g., excessive zero drift between calibrations) by illuminating a light on the System Status Panel. The computer monitors interior shelter temperature, air flow through the manifold, temperature of the manifold, line voltage, zero drift, span drift, hydrogen pressure, ethylene pressure and flame status.

h. Shelter temperature is controlled to $\pm 5F^{o}$.

i. A back-up, power supply system keeps all analyzers, the meteorological tower and the computer operating (and thus warmed to operating temperature) during power failures of less than four hour's duration in all trailers.

j. A battery-powered, digital clock assures that the correct time is associated with all data even after line, power failures.

k. The computer controls many parts of the system eliminating operator error. Included are automatic, power shutoff, if interior temperature exceeds $90^{o}F$, automatic calibration of all analyzers, control of High-Volume particulate samplers, control of the printer and cassette tape unit and illumination of an outside, alarm light if a severe problem develops.

l. All data are recorded on two, separate, cassette units and hardcopy. The cassettes and hardcopy are sent separately to Radian's headquarters according to detailed data handling procedures.

m. All Hi-Vol filters are brought to a constant humidity before and after exposure. Particulates are measured daily at all five stations.

n. All analyzers receive a multi-point calibration at least every 180 days.

o. For the gas-chromatograph-type analyzers a spectrum output is recorded every time the hydrogen bottle is changed.

p. Special audit checks using a different span-gas, calibration source and dilution system are run on request.

q. Instruments are occasionally run for 24 hours on zero and 24 hours on span to assess noise and drift characteristics.

r. Since SO_2 and H_2S are monitored with flame photometric detectors at all stations, a test has begun in which SO_2 is measured on two analyzers at one station, and H_2S on two analyzers at another station. This will be continued for a month and will further define noise and drift characteristics.

s. A catalytic oxidizer is installed on the vent of the ozone analyzers to remove the residual ethylene (a hydrocarbon) that otherwise might be a pollution source which could affect the ambient air concentration.

t. Charcoal scrubbers are installed on the vent of the calibration units using permeation tubes for SO_2 and H_2S to remove these gases that otherwise might be a pollutant source which could affect the ambient air concentrations.

u. Venting all air from the trailer and the battery back-up system occurs through charcoal scrubbers to remove potential pollutants.

v. High,air flow rate is utilized through the sampling manifold to keep the residence sample time in the sampling manifold to a minimum.

w. The manifold is slightly heated to avoid condensation of water vapor since water has a tendency to absorb some pollutants. Also, liquid water entering an analyzer can cause serious problems.

x. The sampling manifold is vented outside the trailer to prevent back diffusion of the trailer's atmosphere into the manifold.

y. All data are machine processed using digitized tape-recorded data, thus eliminating manual processing errors.

z. The entire data acquisition system is checked monthly with a reference voltage source for voltage offsets or other problems.

aa. An analog, strip-chart recorder has been installed in trailer 023,to record H_2S, SO_2 and tower meteorological parameters in the event of power failure,as still another back-up.

ab. Redundant windspeed and direction instrumentation exists at three levels on the meteorological tower.

ac. Statistical significance is assured by the fact that 300,one-second samples are obtained and averaged to obtain a five-minute average for all gaseous and meteorological values except those utilizing the gas chromatograph which yields a five-minute sample. Owing to the instrument accuracies and the data processing techniques errors can be introduced into the reported samples. Table IV-3 shows the maximum possible errors that might be introduced in recording one five-minute sample. It should be noted that this error will not occur frequently and should be very near zero when considered on a statistical average.

ad. Operating efficiency requirements in the lease stipulations are very stringent requiring 90% efficiency on the air-quality parameters and 95% on the tower meteorology over the lease year. Table IV-4 shows the actual operating efficiencies attained by month by constituent, monthly cumulatives and the cumulative composite averaged over all gaseous constituents and meteorological parameters. Although the particulates did not meet the cumulative efficiency requirement at the end of the first year of baseline, the cumulative composite of the air-quality parameters met the 90% requirement and the meteorology composite met the 95% meteorological requirement.

2. E G & G Model Environmental Consultants

To assure quality control in the upper air studies E G & G Environmental Consultants have utilized the following procedures:

a. The E G & G Model 702 portable temperature recorder unit was calibrated to within $\pm$ 0.2F^{o}.

b. The flight path of the aircraft was duplicated as closely as possible for each flight. When possible, the aircraft was flown down to 200 feet above the surface at the tower, an altitude corresponding to the tower top. This was done to verify the accuracy of the aircraft altimeter settings; in all cases the altimeter indicated an elevation of 7200 $\pm$ 50 feet above mean sea level (MSL) for this 7200 foot actual elevation. The aircraft normally flew in a 3000-foot diameter spiral around the tower to 13,000 feet MSL obtaining data every 50 feet in a normal 10 feet/second rate of climb. Aircraft measurements in daylight below 7200 feet MSL were made in a gradually-ascending flight path starting approximately 50 feet above the surface in Piceance Creek in the general direction of the tower. This data obtained below the level of 7200 feet MSL cannot be accurately

Table IV-3

MAXIMUM ERRORS IN RECORDING IN SINGLE SAMPLE

CHANNEL	INSTRUMENT ACCURACY	DATA PROCESSING ERROR*
NO_x	± 5 ppb	± .62
NO	± 5 ppb	± .62
SO_2	± 10 ppb	± .74
H_2S	± 10 ppb	± .74
THC	± 50 ppb	± 1.72
CH_4	± 50 ppb	± 1.72
CO	± 50 ppb	± 1.72
O_3	± 5 ppb	± .62
Wind Speed (met. tower)	± 1.0 mph	± .52 mph
(reg. tower)**	± .5 mph	± .52 mph
Wind Direction (met. tower)	± 5.4 deg	± .63 deg
(reg. tower)	± 5.4 deg	± .63 deg
Temperature (met. tower)	± .45 F°	± .54 F°
(reg. tower)	± .3 F°	± .54 F°
Relative Humidity (met. tower)	± 3.0%	± .52%
(reg. tower)	± 5.0%	± .52%
Change in Temperature	± .18 F°	± .0064 F°
Barometric Pressure	± .5 millibars	± .52 millibars

*Error due to rounding to integers for one five-minute average or sample
**Regular towers are attached to each trailer

These data supplied by RADIAN CORP.

Table IV-4

AIR QUALITY AND METEOROLOGY OPERATING EFFICIENCIES

CHANNEL (NO. OF CHANNELS)		MONTH '74 NOV	DEC	'75 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
MONTHLY OPERATING EFFICIENCIES													
Sulfur Dioxide	(4)	99	98	100	100	95	100	99	97	100	100	99	98
Hydrogen Sulfide	(4)	99	97	100	100	99	100	98	97	99	99	98	100
Particulates	(4)	18	76	75	91	88	100	100	97	100	100	99	100
Nitrogen Oxides (NOX)	(1)	100	97	84	82	52	100	100	87	97	100	100	100
Nitric Oxide	(1)	100	97	84	82	52	100	100	87	100	100	100	100
Total Hydrocarbons	(1)	70	87	81	100	90	100	100	97	100	100	100	87
Methane	(1)	70	87	90	68	87	100	100	97	100	100	100	84
Carbon Monoxide	(1)	77	87	90	100	97	100	100	100	100	100	87	71
Ozone	(1)	93	97	100	96	100	100	100	100	100	100	97	100
Composite	(18)	76.3	90.9	90.5	94.0	89.2	100.0	99.3	96.2	99.6	99.8	98.2	96.3
Wind Speed - 30 Feet	(1)	100	85	100	100	77	100	100	87	100	100	100	100
Wind Speed - 100 Feet	(1)	100	85	100	100	77	100	100	87	100	100	100	100
Wind Speed - 200 Feet	(1)	100	85	100	100	77	100	100	87	100	100	100	100
Wind Direction - 30 Feet	(1)	100	87	100	100	77	100	100	87	100	100	100	100
Wind Direction - 100 Feet	(1)	100	87	100	100	77	100	100	87	100	100	100	100
Wind Direction - 200 Feet	(1)	100	87	100	100	77	100	100	87	100	100	100	100
Relative Humidity - 8,30,100 or 200	(1)	100	87	100	100	77	100	100	87	97	100	100	100
Temperature - 30 Feet	(1)	100	87	100	100	77	100	100	87	100	100	100	100
Temperature - 100 or 200 Feet	(1)	100	87	100	100	77	100	100	87	100	100	100	100
Composite	(9)	100.0	86.3	100.0	100.0	77.0	100.0	100.0	87.0	99.7	100.0	100.0	100.0
MONTHLY CUMULATIVE OPERATING EFFICIENCIES													
Sulfur Dioxide	(4)	99.0	98.5	99.0	99.3	98.4	98.7	96.7	98.5	98.7	98.8	98.8	98.8
Hydrogen Sulfide	(4)	99.0	98.0	98.7	99.0	99.0	99.2	99.0	98.8	98.8	98.8	98.7	98.8
Particulates	(4)	18.0	47.0	56.3	65.0	69.6	74.7	78.3	80.6	82.8	84.5	85.8	87.0
Nitrogen Oxides (NOX)	(1)	100.0	98.5	93.7	90.8	83.0	85.8	87.9	87.8	88.8	89.9	90.8	91.6
Nitric Oxide	(1)	100.0	98.5	93.7	90.8	83.0	85.8	87.9	87.8	89.1	90.2	91.1	91.8
Total Hydrocarbons	(1)	70.0	78.5	79.3	84.5	85.6	88.0	89.7	90.6	91.7	92.5	93.2	92.7
Methane	(1)	70.0	78.5	82.3	78.8	80.4	83.7	86.0	87.4	88.8	89.9	90.8	90.3
Carbon Monoxide	(1)	77.0	82.0	34.7	88.5	90.2	90.8	93.0	93.9	94.6	95.1	94.4	92.4
Ozone	(1)	93.0	95.0	96.7	96.5	97.2	97.7	98.0	98.3	98.4	98.6	98.5	98.6
Composite	(18)	76.3	83.6	85.9	87.9	88.2	90.2	91.5	92.1	92.9	93.6	94.0	94.2
Wind Speed - 30 Feet	(1)	100.0	92.5	95.0	96.3	92.4	93.7	94.6	93.6	94.3	94.9	95.4	95.8
Wind Speed - 100 Feet	(1)	100.0	92.5	95.0	96.3	92.4	93.7	94.6	93.6	94.3	94.9	95.4	95.8
Wind Speed - 200 Feet	(1)	100.0	92.5	95.0	96.3	92.4	93.7	94.6	93.6	94.3	94.9	95.4	95.8
Wind Direction - 30 Feet	(1)	100.0	93.5	95.7	96.8	92.8	94.0	94.9	93.9	94.6	95.1	95.6	95.9
Wind Direction - 100 Feet	(1)	100.0	93.5	95.7	96.8	92.8	94.0	94.9	93.9	94.6	95.1	95.6	95.9
Wind Direction - 200 Feet	(1)	100.0	93.5	95.7	96.8	92.8	94.0	94.9	93.9	94.6	95.1	95.6	95.9
Relative Humidity - 8,30,100 or 200	(1)	100.0	93.5	95.7	96.8	92.8	94.0	94.9	93.9	94.2	94.8	95.3	95.7
Temperature - 30 Feet	(1)	100.0	93.5	95.7	96.8	92.8	94.0	94.9	93.9	94.6	95.1	95.6	95.9
Temperature - 100 or 200 Feet	(1)	100.0	93.5	95.7	96.8	92.8	94.0	94.9	93.9	94.6	95.1	95.6	95.9
Composite	(9)	100.0	93.2	95.4	96.6	92.7	93.9	94.8	93.8	94.4	95.0	95.5	95.8

termed "vertical" temperature soundings above the tower.

c. The vertical wind structures from the surface to 13,000 feet MSL, or cloud base, were determined four times per day with 30-gram,pilot balloons in conjunction with a theodolite. The theodolite was aligned to magnetic north and then corrected to true north by rotating it 15 degrees counterclockwise. The balloons were carefully "weighed off," using a standard,National Weather Service,inflation kit for 30-gram balloons inside an enclosed shelter to negate the influence of wind,and then released at the SG-10 well-site north-northwest of the Tract C-b,main,meteorological tower. These balloons rise at an approximately constant rate of 600 feet per minute. The balloons were released at 0500, 0800, 1100 and 1700 hours MST in conjunction with the temperature soundings. At 30-second intervals azimuth and elevation were vocally recorded to within 1.0 degree, although interpolations were attempted to within 0.1 degree.

3. Multiple Source Comparisons

Regarding comparisons of similar data obtained from two or more sources, data quality is enhanced as follows:

a. Atmospheric stability assessments from as many as seven different techniques were made including temperature soundings, tower temperature increments, wind speed, solar radiation index, standard deviations of both the horizontal and vertical components of wind direction and the acoustic sounder.

b. A correlation study on inversion frequency and height between the acoustic sounder at station 023 and the aircraft soundings is in progress.

4. Dames and Moore

With regard to the Dames and Moore visibility study utilizing photographic photometry:

a. In addition to the photography pertinent,visibility information is recorded each hour in a Site Log by the photographer to supplement the photographic study. Remarks are recorded each hour on the local weather conditions, restrictions to vision and view useability with additional comments for any unusual occurrences such as camera malfunctions or site visits.

b. Processing of the black and white film is accomplished in the Dames & Moore Laboratory under closely controlled conditions. Photographic chemicals are frequently replaced and processing temperatures held to within a $\pm 2F^{o}$ tolerance. Color film is not used to provide numerical data, thus it is developed through commercial sources. Prior to development of the black and white film the leading end of each film roll is exposed to a calibrated series of 11 different light intensities. Each film roll is exposed to these light intensities in a Kodak, Process Control Sensitometer, Model 101. Once development of the film roll is complete, the densities of the 11 steps, referred to as a sensitometric strip, are obtained with a MacBeth TD504 Densitometer. These densities, when plotted versus the logarithm of exposure, determine a characteristic curve for that particular film roll.

c. Parameters used in the calculation of the visual-range, such as the object distance and film density, are each checked or calibrated against known quantities. Object distance, for example, is measured by two methods:

i) Line-of-sight aircraft flights for the measurement of camera-to-object distances and the identification of each object on a United States Geological Survey (USGS) topographic map.

ii) Measurement of the object-to-camera distances on USGS topographic maps.

The two methods used to determine camera-to-object distances generally agree within five percent although the distances obtained from the USGS maps always take precedence.

d. The characteristic curve, which defines the exposure-film density relation, is determined from a sensitometric strip placed on each film roll as described previously. The sensitometer used to install this strip is factory calibrated and the light source is replaced at the manufacturer's recommended intervals.

e. Density values obtained from each film roll are measured with a densitometer calibrated with a step wedge similar to the sensitometric strip. The densitometer is calibrated before and after reading image densities from each film roll but typically requires no adjustments. The repeatability of the instrument is $\pm$ .01 density units.

f. No specific precision data exist for the technique used to measure visibility; however, the total error involved is estimated to be less than five percent.

g. Statistical significance is assured by reporting data on a quarterly basis; of the possible 308 visual range measurements on scheduled days, 270 measurements were obtained in the fall quarter for an 88 percent recovery; no days occurred, however, in which less than one-half of the measurements were obtained.

C. Results and Discussion

1. Meteorology

The meteorological conditions that prevailed in the Tract C-b region during the period November, 1974 to October, 1975 were often quite diverse because of terrain influences. The meteorology of the three stations in the Piceance Creek valley (Stations 020, 021 and 022) was dominated by the effects of the two local circulation cells, the katabatic (downslope) and anabatic (upslope) cells. On the plateau the meteorological tower (Station 023) and Station 024 normally experienced conditions that were macroscale in nature (e.g., wind directions and speeds that were induced by synoptic-scale pressure gradients and thermal fields that reflected large-scale patterns). Precipitation totals, especially snowfall, were normally greater on the plateau than in the valley because of the orographic lifting up and over the plateau. See Table II C-19 of the 5th Quarterly Summary for monthly precipitation values.

The walls of the Piceance Creek valley had a marked channeling effect on the wind. The wind roses for the valley stations (Figure II C-3, 5th Quarterly Summary) exhibited primarily a northwest-southeast flow couplet during the twelve-month period. The southeasterly winds were caused by the nighttime and morning katabatic circulation, while the northwesterly winds, induced by the anabatic circulation cell were primarily an afternoon phenomenon. Channeling effects from the terrain concentrated the winds associated with these localized circulations. The katabatic cell was more strongly developed during the winter months, while the anabatic cell was more strongly developed during the summer months. However, since the anabatic cell never attained the strength of the katabatic cell (approximately a ratio of 1 to 2 with regard to directional persistence) and since winds were generally light and variable on a synoptic scale during much of the summer, the wind roses for the Piceance Creek valley show more directional variability during the later spring and summer months. The effects of channeling and the local circulations are most marked at Station 022.

The wind roses for Station 023 and the meteorological tower, where channeling and localized effects are not significant, show that the winds had a westerly component during most of the period (Figure II C-2

of the 5th Summary and IV-2 of this report). This westerly influence is because of synoptic-scale effects, since the basic flow of the long-wave pattern is west-to-east. South-southwesterly winds were most common at this location. Because of its elevation and exposure, the meteorological tower also experienced much stronger winds than did the other monitoring sites. The Ekman spiral effect was evident at the tower, since the winds generally veered in direction and increased in strength as a function of increasing height, the speed increase being approximately logarithmic as indicated in Table IV-5.

The katabatic and anabatic influences were both evident at Station 024, which is located in a transition zone between the meteorological conditions of the Piceance Creek valley and those of the plateau. The anabatic flow generally affected all five monitoring sites to varying degrees and the katabatic flow generally affected only the lower elevations. On the nights and the mornings when this drainage or katabatic flow was well-developed, it affected the valley trailers as well as Station 024 and the 8- and 30-foot levels of the meteorological tower. The katabatic effects seldom reached the 100- and 200-foot levels of the meteorological tower.

Both average and maximum wind speeds for each month have been summarized in Table II C-18 of the 5th Quarterly Summary. Annual three-dimensional "mats" depicting percentage of occurrence as a function of both wind speed and direction are presented on Figure IV-3 for Station 023 (typical for the plateau sites) and Station 022 (typical for Piceance valley stations). The maximum wind speed measured over a five-minute period was 56 mph on the plateau in April, 1975. Gusts during the first year of baseline reached 79 mph. Hourly average, wind speeds have ranged from three mph to ten mph, and are generally higher on the plateau than in Piceance Creek valley. Extreme wind speeds (as 30-second gusts) have been estimated over the 30-year design life of the project. If design life is equated to the return period for this gust, a 92 mph design wind speed results at a 5% risk level. This risk corresponds to a design gust of this magnitude not being exceeded more than once in the design life of the project.

Because of the katabatic effects, temperatures were often considerably colder in the Piceance Creek valley than on the plateau during relatively calm, clear nights. During these nights, which had radiational cooling, intense ground-based inversions formed. The top of the inversions normally reached elevations that were above the top of the meteorological tower. However, the most stable conditions normally occurred near the ground especially in the Piceance Creek valley. Because of the surrounding valley walls and the relatively low elevation of the site (cold air drainage), Station 021 usually had a minimal nocturnal wind flow (i.e., little vertical mixing) and, therefore, normally had the lowest minimum temperatures. In fact nighttime temperatures were often 30F° colder at Station 021 than atop the plateau. During the afternoons, when vertical mixing of the air was well established, temperatures were fairly uniform throughout the Tract C-b region. However, afternoon temperatures were slightly lower on the plateau than they were in the Piceance Creek

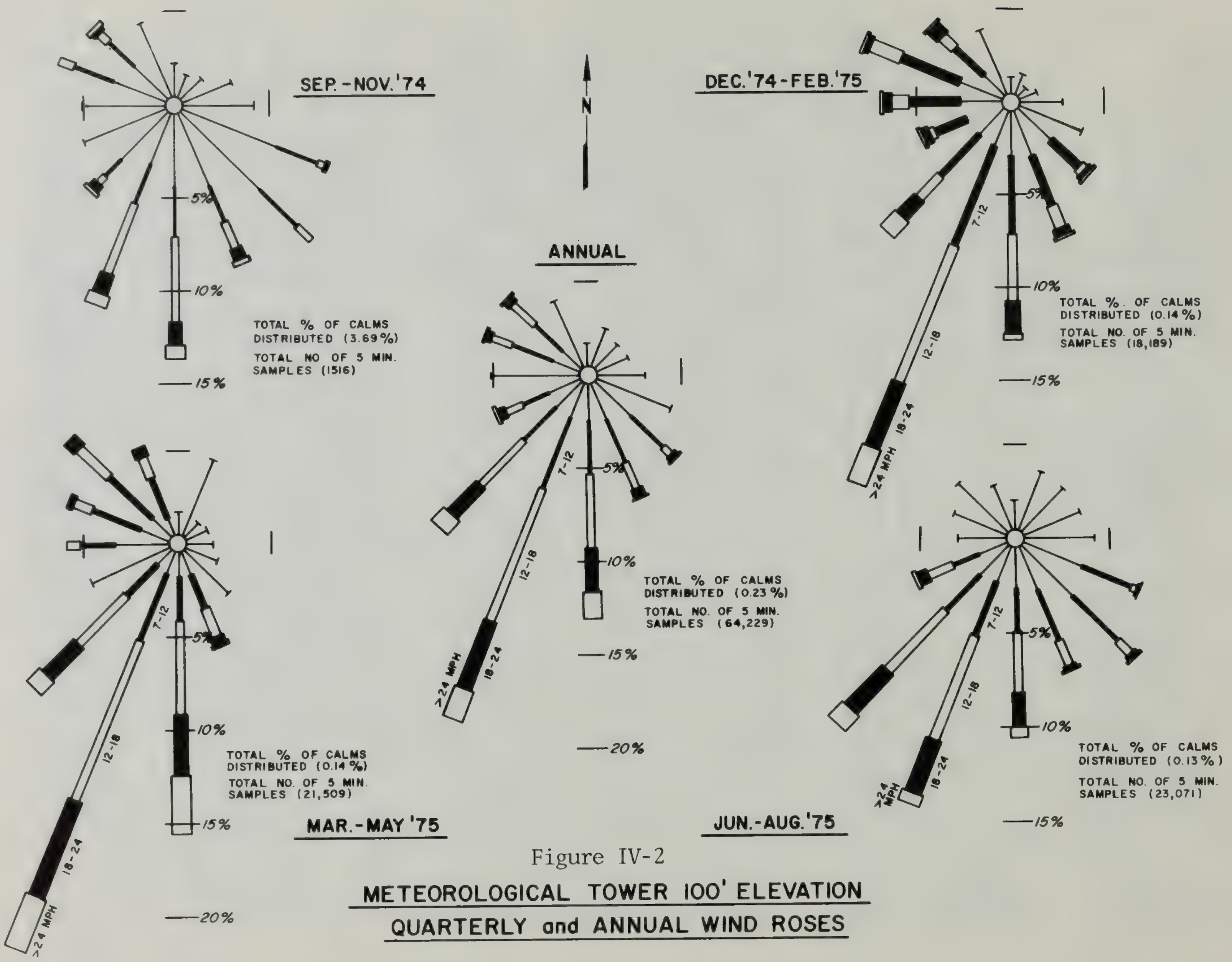


Figure IV-2

METEOROLOGICAL TOWER 100' ELEVATION
QUARTERLY and ANNUAL WIND ROSES

Table IV-5 . **METEOROLOGICAL SUMMARY: VERTICAL WIND PROFILE (MPH)**
(Met. Tower)
1974-1975

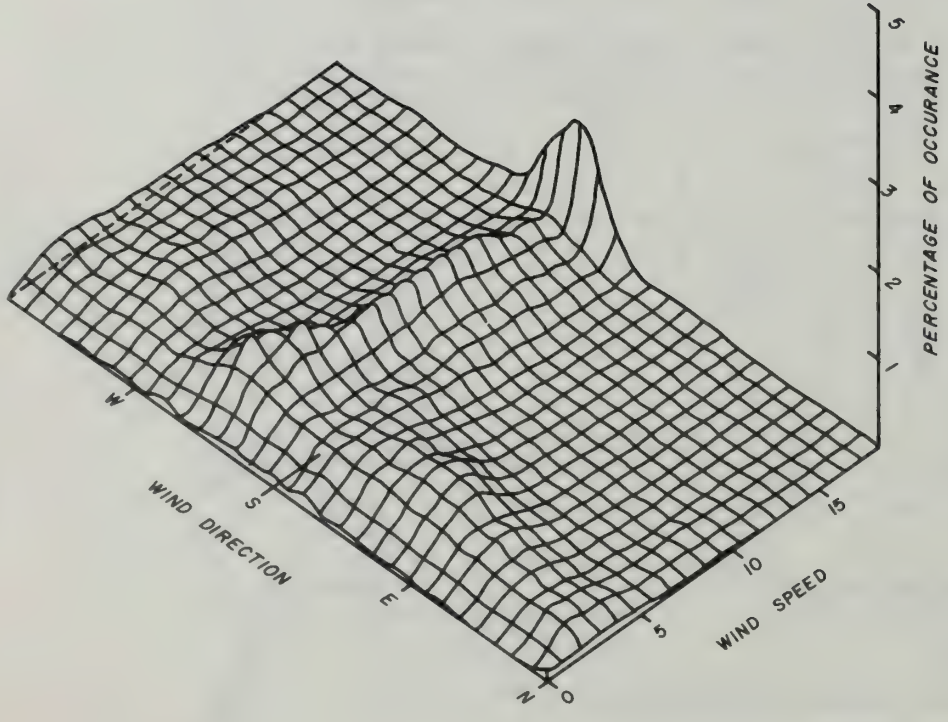
Height on Tower (Feet) (z)	Arithmetic Mean Hourly Wind Speed for the Month												Annual
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	
8	4	5	5	5	7	7	6	6	4	5	4	6	5
30	7	7	8	8	10	10	9	8	7	8	6	8	8
100	8	9	10	10	12	11	11	10	8	10	7	10	9
200	8	9	10	10	13	12	11	10	8	10	7	11	10
Constants for Logarithmic Fit (1)													
v^*/k (MPH)	1.26	1.39	1.57	1.57	1.95	1.85	1.70	1.57	1.26	1.57	1.09	1.57	1.53
v^* (MPH)	0.50	0.56	0.63	0.63	0.78	0.74	0.68	0.63	0.50	0.63	0.44	0.63	0.61
z_o (ft.)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22

(1) Assumed form of equation:

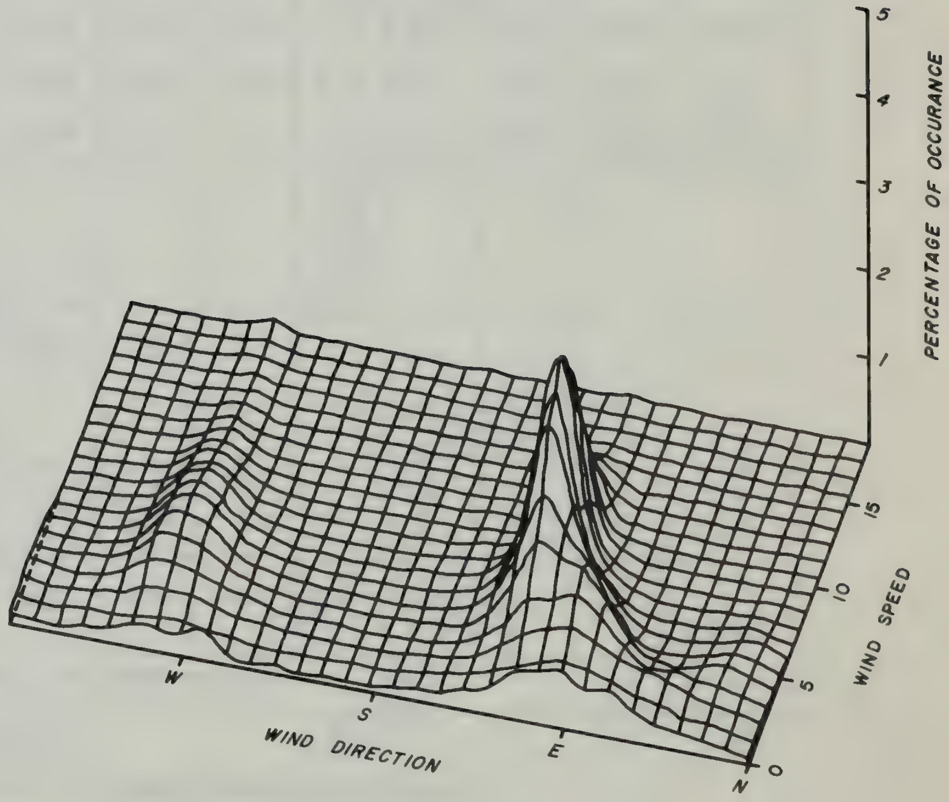
$v(z) = \frac{v^*}{k} \ln (z/z_o)$ where
$v(z)$ = Mean wind speed at height z above surface
v^* = Friction velocity
z_o = Roughness length
k = von Karman's constant = 0.4

Figure IV-3 **ANNUAL SUMMARY OF WIND DATA**

TRAILER 023



TRAILER 022



valley owing to lapse rate considerations. Hourly mean temperature variations for each month as well as hourly maxima and minima are depicted on Figure IV-4. Station 021 exhibited the largest range of hourly extremes (in January) from -51° to +54°F. Maximum hourly temperature measured was 90°F in June and July, 1975; the minimum (occuring in January) was -51°F at Station 021 in Piceance valley.

Relative humidity (Table II C-17 of the 5th Quarterly Summary) has ranged from 8% to 100%. Hourly averages for each month vary from 72% on the plateau to 75% in the Piceance Creek valley during the winter; in the summer these two averages decrease to 29% and 39%, respectively. The annual average is generally higher in the Piceance Creek valley than on the plateau. This is consistent with cooler average temperatures in the valley.

Inversions in the vicinity of the Tract have been measured in upper air studies with aircraft and with acoustic sounders. The height to the top of the inversion can be determined by plotting temperature versus height and noting where the slope of the air temperature curve changes from negative to positive.

This type of data was obtained by aircraft temperature soundings as part of the upper air studies. Data have been taken during the four quarters for a period of 15 days per quarter. A summary of the inversion data to date is shown in Table IV-6. This table indicates the number of days when inversions occurred over Piceance Creek valley and over the Tract. Summing up the data for the four quarters, inversions were observed about 57% of the test days over Piceance Creek valley, 77% of the days over Tract C-b, 89% of the days over either Piceance Creek valley or the Tract and 45% of the days over both areas. Though a higher frequency of inversions is normally expected in the canyons rather than atop the plateau, the data in Table IV-6 indicate otherwise. It should be recognized that because of sampling techniques, aircraft flights cannot be made in the canyons in the dark (e.g., a 5:30 a.m. flight) and, as a result, some existing inversions in the canyons may not have been reported.

While upper-air,temperature soundings are the most accurate means of determining inversion heights, this method was used for only 15 days per quarter and then only during parts of each day. For these reasons and because a continuous record of the onset of inversions is desirable, two acoustic sounders were installed. One is on the Tract (near the meteorological tower) and one is in Piceance Creek valley (near the Rock School station 021). A summary of the number of inversions and their average duration and height is given in Table IV-7. Fifty-four percent of the inversions recorded were less than seven hours in duration and 42% persisted from 7 to 22 hours. The influence of the solar regime on inversion frequency and duration is apparent in that the more numerous, shorter duration inversions occurred during the summer months and the longer lasting inversions occurred during the winter months. In summer, surface heating and convection are greater and effectively disperse the stable layers creating short duration inversions which are not so well-

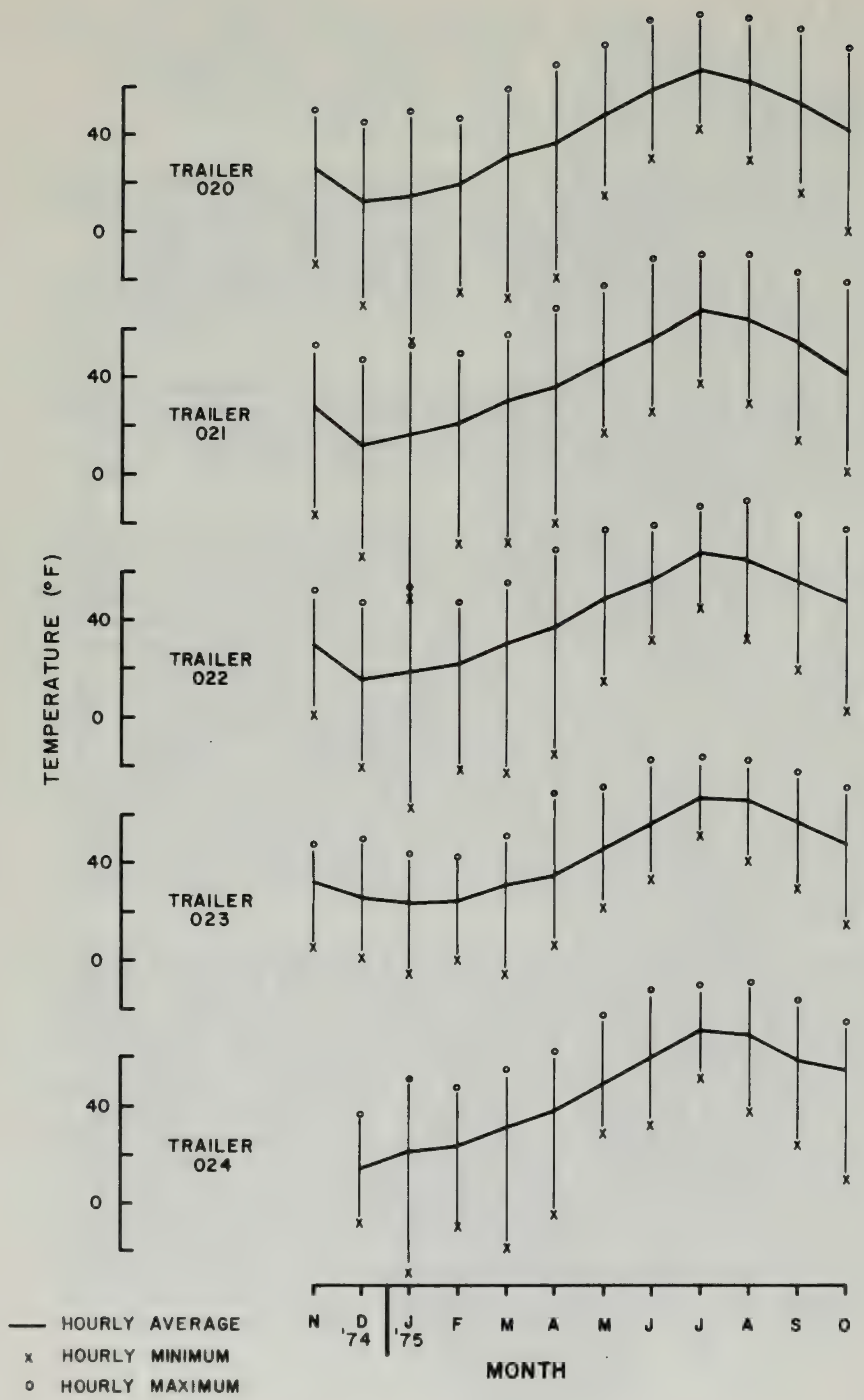


Figure IV-4 AIR TEMPERATURE VARIATIONS

Table IV-6 SUMMARY OF INVERSIONS AT THE C-b TRACT
(Source: Temperature vs. Altitude Data)

Item	Fall '74 (Oct.)	Winter '75 (Jan.)	Spring '75 (Apr.)	Summer '75 (July)	Cumulative
No. of Days with Inversions					
In Canyons below Tract (=C)	4	8	5	15	32
Above Tract Surface (=T)	11	11	7	14	43
C or T	12	13	10	15	50
C and T	3	6	2	14	25
No. of Successful* Days without Inversions	0	2	4	0	6
Total No. of Successful* Days of Test	12	15	14	15	56
Percentage of Days with Inversions **					
C	33.3	53.3	35.7	100.	57.2
T	91.6	73.3	50.0	93.3	76.8
C or T	100.0	86.6	71.4	100.	89.2
C and T	25.0	40.0	14.3	93.3	44.6

* A "success" is defined here as one for which (a) at least two successful flights were obtained and for which one of the flights was either at nominally 6 am or 9 am or (b) one inversion was obtained.

$$\text{**Percentage of Days with Inversions} = \frac{\text{No. of Days with Inversions x 100\%}}{\text{No. of Successful Days of Test}}$$

Table IV-7 Means and standard deviations of inversion durations and maximum, minimum, and average inversion heights by month as obtained from acoustic sounder data @ Station 023.

Month	Number of Days of Measurement	Number of Inversions Recorded	Inversion Duration (hrs) Mean	Inversion Duration (hrs) Std Dev	Maximum Inversion Heights (ft) Mean	Maximum Inversion Heights (ft) Std Dev	Minimum Inversion Heights (ft) Mean	Minimum Inversion Heights (ft) Std Dev	Average Inversion Heights (ft) Mean	Average Inversion Heights (ft) Std Dev
December	25	19	16	11	1207	461	421	277	796	332
January	30	24	14	7	1417	354	604	366	1019	386
February	28	25	12	4	1467	358	383	157	925	239
March	27	28	6	3	1383	485	693	371	1028	442
April	21	28	4	3	932	370	468	223	686	266
May	29	26	5	3	884	347	457	192	673	263
June	0	(no measurements were made in June)								
July	15	33	3	2	1760	709	764	400	1202	483
August	11	11	6	4	1414	508	555	369	945	436
September	14	16	10	5	1029	291	242	113	559	166

defined as those occurring in winter. Regarding time of onset, 84% of the inversions recorded were found to begin between the hours of 1600 and 0330 MST. In winter, the onset time occurred during a broader spectrum of time periods while in summer the onset time more frequently occurred after sunset or nearer midnight as radiation cooling became effective in allowing the formation of stable layers. Dissipation of inversions, in general, is related to the time of sunrise; stable layers dissipated most often between 0400 and 0930 MST. The prevailing synoptic weather pattern may also cause dissipation and therefore time periods other than those near sunrise are encountered.

Although the time period during which both acoustic echo sounders have been in operation is short, some initial comparisons can be made. At the Rock School station, the pooling of cool air in the valley appears to create longer lasting inversions which were somewhat lower in height than those recorded at Station 023. Measurements at the Rock School site exhibited inversion formation times similar to those of Station 023, but dissipation times were later because of the higher sun angle required to heat (expose) the surface in the valley bottom during the late summer.

Atmospheric stability can be defined by using Pasquill-Gifford stability classes (Table IV-8). In this arbitrary system there are 7 classes (Class A through Class G) with Class A being the most unstable and Class G the most stable. Stability can be determined by upper air temperature soundings, by temperature measurements at various levels on the meteorological tower, by measurements of the horizontal and vertical wind directions at various levels on the meteorological tower and by a combination of solar radiation and wind speed data. Since the upper air temperature soundings are not a continuous source of data, the other methods of determining stability (all of which are continuous sources of data) were correlated with the temperature soundings to determine which method could be used most readily and reliably. This comparison showed that the best method of continuously determining stability classes was to use the temperature differences between the 200-foot level and the 30-foot level on the meteorological tower. This method was shown to always be in agreement, within at least one stability class, with the stability class determined from upper air data. Using the meteorological tower, temperature-difference method the monthly average stability classes for each hour were developed. These are shown in Table IV-9. The monthly average stability class frequencies are presented in Table IV-10. These two tables show that in the fall and winter months the air masses are generally more stable (Classes E and F) than in the spring and summer (Classes A and B). Generally in the fall and winter the air mass is more stable during the daylight hours than at night. During the spring and summer the air mass become less stable during the daylight hours, probably owing to warming of the air.

Relevancy of this meteorology discussion to oil shale development may not be readily apparent; therefore the following should be underscored: 1) tract baseline climatology needs definition so that any trends or changes due to development can be noted; 2) "Worst-case" meteorological conditions are estimated utilizing the baseline data. Associated atmospheric

Table IV-8 DETERMINATION OF PASQUILL-GIFFORD STABILITY CLASSES FROM VARIOUS SOURCES

Pasquill-Gifford Stability Class	Slope of the Temperature-Altitude Curve dT/dz (°C/100m)	Standard Deviations of Wind Direction Components: Horizontal $\sigma\theta$ (Deg.)	Vertical $\sigma\phi$ (Deg.)
A	< -1.9	> 23	
B	-1.9 to -1.7	18 to 23	> 15
C	-1.7 to -1.5	13 to 18	9 to 15
D	-1.5 to -0.5	8 to 13	6 to 9
E	-0.5 to 1.5	4 to 8	2 to 6
F	1.5 to 4.0	2 to 4	0 to 2
G	> 4.0	< 2	

Table IV-9 AVERAGE HOURLY STABILITY CLASSES

As Obtained From Temperature Differences Between 200 ft. & 30 ft. On The Met. Tower

Month	Hour																								Average
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Nov.	E	E	E	E	E	E	E	F	F	F	F	F	F	F	E	E	E	E	E	E	E	E	E	E	E
Dec.	E	D	D	E	D	D	E	E	E	F	F	F	F	E	E	E	E	D	D	D	D	D	D	D	E
Jan. '75	D	D	D	D	D	D	D	D	E	E	E	E	E	E	E	E	D	D	D	D	D	D	D	D	D
Feb.	E	E	E	E	E	E	E	E	E	D	D	C	C	C	C	C	D	E	E	E	E	E	E	E	D
Mar.	D	D	D	D	D	C	C	C	A	A	A	A	A	A	A	A	A	A	C	C	D	D	D	D	C
Apr.	D	D	D	D	D	D	C	B	B	B	A	A	A	A	A	A	A	B	C	D	D	D	D	D	C
May	D	D	D	D	D	D	C	B	A	A	A	A	A	A	A	A	A	A	B	C	D	D	D	D	B
June	E	E	E	E	E	E	D	B	A	A	A	A	A	A	A	A	B	B	B	C	D	D	E	E	C
July*	–	–	–	–	–	–	–	–	–	–	–	A	A	A	A	A	A	B	–	–	–	–	–	–	A*
Aug.	F	F	F	F	F	F	F	D	B	A	A	A	A	A	A	A	A	B	D	E	F	F	F	F	D
Sept.	F	F	F	F	F	F	F	E	B	A	A	A	A	A	A	A	A	C	E	E	E	F	E	F	D
Oct.	E	E	E	E	E	E	E	D	C	A	A	A	A	A	A	A	A	C	D	D	E	E	E	E	C

*Partial Data Only

Table IV-10 METEOROLOGICAL SUMMARY: STABILITY CLASS FREQUENCIES (%)
1974-1975

Source: Met. Tower
(200' to 30')

Pasquill-Gifford Stability Class	dT/dz Range for this Stability Class (°C/100m)	Month												Annual
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	
A	<– 1.9	2.0	17.4	12.5	6.3	45.4	48.4	57.2	42.9	75	35.8	33.0	39.3	34.6
B	–1.9 to –1.7	0.4	1.3	2.7	1.5	6.5	4.1	3.1	4.6	2.5	4.4	3.4	3.1	5.0
C	–1.7 to –1.5	0	1.5	3.8	0.7	6.5	3.9	2.8	4.4	0	2.2	2.8	4.8	2.8
D	–1.5 to –0.5	5.3	19.0	22.6	33.7	27.0	20.6	12.3	16.1	0	7.5	8.0	11.7	15.3
E	–0.5 to +1.5	62.8	40.3	31.5	41.8	14.1	17.7	12.2	17.7	0	15.1	23.5	18.7	24.6
F	>1.5	29.5	20.5	26.9	16.0	0.5	5.3	12.4	14.3	0	35.0	29.3	22.4	17.7
Total		100	100	100	100	100	100	100	100	100	100	100	100	100

stability conditions and wind velocity are input to computer atmospheric diffusion models used to assess potential air-pollution increments attributed to either an oil-shale plant or transportation systems or both. Comparison with allowable standards then allow potential air pollution violations to be assessed and eliminated via design trade-offs early in the plant-design process before the plant is built; 3) Climatological extremes expected over the project, design life serve as structural design criteria, e.g., peak wind speeds, precipitation rate and amount (snow-load), temperature extremes, frost depths.

2. Air Quality

The first year of baseline air quality data covering the period from November, 1974 thru October, 1975 is summarized in the Radian Annual Summary Report and is included as part of the Quarterly Data Report #5. The Radian report includes: 1) The twelve-month summaries for the two highest concentrations for each gas and the particulates by station for the appropriate averaging-time periods specified in Federal and State air quality regulations. The annual averages are also presented in these tables and are included in Tables IV-11 to IV-15 as part of this report; 2) The ten, highest, one-hour, sulfur dioxide, and 24-hour, particulate concentrations. These are also presented in this report in Tables IV-16 and IV-17, respectively. Graphic presentations included in Quarterly Data Report #5 are: 1) Daily concentrations of each gas by station plotted over the one-year period. Examples are shown for ozone and for hydrogen sulfide and sulfur dioxide; 2) Three-dimensional plots correlating the average of each measured gas concentration with a given wind speed and wind direction by trailer (Several examples are shown for hydrogen sulfide and sulfur dioxide in this report); and 3) Plots showing the diurnal variation of the ratio of nitrogen dioxide concentration to non-methane hydrocarbon concentration as compared to the diurnal variation of ozone.

The three-dimensional plots illustrate the tendency for the higher gas concentrations to coincide with wind speeds over 10 mph. This trend is most prevalent at Stations 020 and 023 for hydrogen sulfide, sulfur dioxide, oxides of nitrogen, methane, non-methane hydrocarbons, carbon monoxide and ozone and at Station 021 for hydrogen sulfide and sulfur dioxide. Moreover, these plots do not indicate peak ambient gas concentration patterns that coincide with the prevailing wind direction.

In general the air quality program on the Tract has shown that the average background concentrations of the constituents monitored are fairly low. The data, however, have also shown that in this portion of the Piceance Creek Basin relatively high, short-term (one hour or longer) concentrations of most of the constituents measured can also exist. This indicates, that while this area is largely undeveloped and rural in nature, the influence of man or nature can have significant short-term effects on the ambient air quality.

The long-term and monthly averages for the ambient air concentrations are shown in Table IV-18 while the short-term monthly one-hour maximum concentrations are shown in Table IV-19. Sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) are normally below the five parts-per-billion-by-volume detection threshold of the instrumentation (see the Radian monthly

Table IV-11

TWELVE-MONTH SUMMARY (NOVEMBER 1974-OCTOBER 1975)
(Concentrations in Micrograms Per Cubic Meter)

Trailer 020

Parameter	Average	Maximum 24 Hour Value	Maximum 24 Hour Time	Maximum 8 Hour Value	Maximum 8 Hour Time	Maximum 3 Hour Value	Maximum 3 Hour Time	Maximum 1 Hour Value	Maximum 1 Hour Time	Maximum 5 Minutes Value	Maximum 5 Minutes Time
SO_2	.8	1) 30.2	3/7 10:00			1) 31.5	3/7 9:50	1) 33.9	9/14 13:10	1) 143.3	7/14 12:05
		2) 19.2	6/22 13:00			2) 31.0	3/7 23:25	2) 32.8	3/7 10:05	2) 109.4	10/29 11:45
H_2S	.1							1) 30.2	3/7 10:00	1) 70.6	8/23 10:35
								2) 21.7	6/15 6:00	2) 55.4	6/30 21:35
Particulate	9.5	1) 133.	11/29								
		2) 70.	5/20								
THC	930.6					1)2294.6	5/13 6:00			1)3256.2	8/20 12:15
						2)2200.8	5/20 6:00			2)3256.0	1/25 10:00
CH_4	851.7					1)1298.0	2/3 6:00			1)3254.2	7/14 18:55
						2)1219.5	12/8 6:00			2)3232.1	12/24 2:00
NMHC	74.3					1)1485.8	2/11 6:00			1)2070.9	12/5 15:55
						2) 707.7	4/22 6:00			2)1820.2	12/4 1:00
O_3	68.8							1)160.4	6/26 14:00	1) 314.5	3/15 14:05
								2)147.2	6/26 15:05	2) 289.0	12/12 11:50
NO_x	10.1							1) 53.2	8/17 6:35	1) 146.0	4/27 16:05
								2) 51.3	9/3 6:25	2) 91.7	8/11 12:15
NO	5.8							1) 44.3	11/10 5:50	1) 146.0	4/27 16:05
								2) 43.7	1/22 7:30	2) 84.0	1/30 3:25
CO	1080				(1)		(1)			1)5698.0	1/11 19:40
					(1)		(1)			2)5698.0	1/25 10:00
NO_2	4.1							1) 36.0	12/3 17:10	1) 69.3	10/27 0:00
								2) 33.9	7/14 13:10	2) 58.0	9/3 4:25

(1) Data to be reported at later date

Table IV-12

TWELVE-MONTH SUMMARY (NOVEMBER 1974-OCTOBER 1975)
(Concentrations in Micrograms Per Cubic Meter)

Trailer 021

Parameter	Average	Maximum 24 Hour Value	Time	Maximum 8 Hour Value	Time	Maximum 3 Hour Value	Time	Maximum 1 Hour Value	Time	Maximum 5 Minutes Value	Time
SO_2	1.3	1) 43.1 2) 18.6	6/16 9:00 11/25 22:00			1) 66.4 2) 61.1	6/16 12:55 6/16 16:00	1) 67.9 2) 65.8	6/16 13:45 6/16 15:15	1) 640.0 2) 117.2	1/26 15:05 6/16 13:00
H_2S	.6							1) 62.6 2) 62.6	4/14 0.35 4/14 1:40	1) 107.9 2) 87.2	1/18 10:05 1/20 22:05
Particulate	10.2	1) 125.0 2) 97.0	4/25 5/20								
THC											
CH_4											
NMHC											
O_3											
NO_x											
NO											
CO											
NO_2											

Table IV-13

TWELVE-MONTH SUMMARY (NOVEMBER 1974-OCTOBER 1975)
(Concentrations in Micrograms Per Cubic Meter)

Trailer 022

Parameter	Average	Maximum 24 Hour Value	Maximum 24 Hour Time	Maximum 8 Hour Value	Maximum 8 Hour Time	Maximum 3 Hour Value	Maximum 3 Hour Time	Maximum 1 Hour Value	Maximum 1 Hour Time	Maximum 5 Minutes Value	Maximum 5 Minutes Time
SO_2	.5	1) 14.1	6/11 3:00			1) 26.9	6/12 0:00	1) 27.4	6/12 0:00	1) 140.7	2/22 9:45
		2) 13.9	5/23 10:00			2) 25.6	6/12 22:30	2) 27.1	6/12 1:15	2) 135.5	3/23 9:35
H_2S	.3							1) 14.3	2/28 20:55	1) 84.4	3/3 9:30
								2) 14.1	3/1 0:00	2) 84.4	3/23 9:35
Particulate	8.2	1) 154.0	11/28								
		2) 116.0	12/1								
THC											
CH_4											
NMHC											
O_3											
NO_x											
CO											
NO_2											

Table IV-14

TWELVE-MONTH SUMMARY (NOVEMBER 1974-OCTOBER 1975)
(Concentrations in Micrograms Per Cubic Meter)

Trailer 023

Parameter	Average	Maximum 24 Hour Value	Maximum 24 Hour Time	Maximum 8 Hour Value	Maximum 8 Hour Time	Maximum 3 Hour Value	Maximum 3 Hour Time	Maximum 1 Hour Value	Maximum 1 Hour Time	Maximum 5 Minutes Value	Maximum 5 Minutes Time
SO_2	1.0	1) 43.0	1/1 11:00			1) 87.7	12/21 0:10	1) 97.9	12/21 1:55	1) 200.6	12/22 14:45
		2) 31.8	12/12 16:00			2) 59.2	8/20 4:00	2) 59.9	8/20 4:15	2) 127.0	1/23 15:40
H_2S	1.7							1) 71.2	7/9 0:10	1) 113.5	3/9 10:15
								2) 70.1	7/9 1:20	2) 91.3	2/22 14:35
Particulate	11.2	1) 112.0	4/25								
		2) 107.0	5/20								
THC*	965.1					1) 3256.1	1/4 6:00			1) 3256.0	1/1 0:20
						2) 2505.4	1/13 6:00			2) 3256.0	1/2 0:15
CH_4*	849.0					1) 1137.7	1/1 6:00			1) 3117.0	1/23 17:45
						2) 1029.5	9/12 6:00			2) 2253.9	6/24 10:45
NMHC*	130.8					1) 2316.0	1/4 6:00			1) 2763.2	9/17 0:25
						2) 1426.4	2/6 6:00			2) 2473.0	1/25 11:05
O_3	68.0							1) 152.2	6/26 13:05	1) 781.5	2/23 22:20
								2) 145.9	3/8 11:40	2) 455.2	3/8 11:50
NO_x	3.9							1) 121.9	1/16 1:20	1) 256.0	1/1 2:20
								2) 121.9	1/17 9:55	2) 256.0	1/10 13:00
NO	2.4							1) 114.2	1/17 9:55	1) 228.0	1/10 13:00
								2) 101.9	1/17 7:00	2) 189.0	1/1 2:20
CO*	683.3			(1)				(1)			(1)
				(1)				(1)		2) 5382.6	6/24 10:45
NO_2	1.5							1) 68.2	1/16 9:15	1) 95.0	1/16 10:15
								2) 67.6	1/16 5:40	2) 89.0	1/5 9:35

(1) Data to be reported at later date

*Average over 9 months (2/1/75 - 10/31/75).

Table IV-15

TWELVE-MONTH SUMMARY (NOVEMBER 1974-OCTOBER 1975)
(Concentrations in Micrograms Per Cubic Meter)

Trailer 024

Parameter	Average	Maximum 24 Hour Value	Maximum 24 Hour Time	Maximum 8 Hour Value	Maximum 8 Hour Time	Maximum 3 Hour Value	Maximum 3 Hour Time	Maximum 1 Hour Value	Maximum 1 Hour Time	Maximum 5 Minutes Value	Maximum 5 Minutes Time
SO_2	1.3	1) 28.9	4/13 12:00			1) 77.9	12/10 6:05	1) 128.5	12/10 6:20	1) 218.8	10/11 20:00
		2) 25.8	3/3 12:00			2) 53.9	5/2 3:10	2) 56.4	5/2 3:20	2) 161.5	12/10 7:10
H_2S	.4							1) 70.9	6/22 19:05	1) 148.1	6/22 17:30
								2) 56.9	5/2 1:40	2) 143.9	6/23 8:15
Particulate	7.8	1) 178.0	11/27								
		2) 162.0	11/29								
THC											
CH_4											
NMHC											
O_3											
NO_x											
NO											
CO											
NO_2											

Table IV-16

TEN HIGHEST ONE (1)-HOUR SO_2 AVERAGES

Site		1	2	3	4	5	6	7	8	9	10
020	Concentration (μg/m^3)	33.9	32.8	31.3	31.0	31.0	31.0	20.8	20.6	20.6	20.4
	Date/Time	7/14	3/7	3/8	3/7	3/7	3/8	6/23	6/23	6/23	6/23
		13:10	10:05	3:05	11:10	23:25	0:45	4:45	1:20	2:40	5:50
	Wind Speed (mph)	1	10	5	10	5	1	7	4	7	7
	Wind Direction	157	186	113	189	111	107	134	107	139	134
021	Concentration (μg/m^3)	67.9	65.8	63.2	60.3	56.0	53.4	34.3	32.8	32.8	31.7
	Date/Time	6/16	6/16	6/16	6/16	6/16	1/26	5/5	11/1	3/7	5/5
		13:45	15:15	16:20	17:25	18:30	14:05	10:50	1:35	10:05	11:55
	Wind Speed (mph)	15	19	16	7	1	10	6	5	9	7
	Wind Direction	304	309	320	320	339	177	148	133	192	158
022	Concentration (μg/m^3)	27.4	27.1	26.5	26.3	26.0	20.8	18.2	18.0	17.8	17.6
	Date/Time	6/12	6/12	6/11	6/11	6/11	12/20	5/23	5/24	5/24	5/23
		0:00	1:15	21:05	19:30	16:45	1:15	20:55	2:25	3:40	14:05
	Wind Speed (mph)	7	9	0	3	6	6	3	2	1	3
	Wind Direction	123	117	71	41	282	116	80	61	97	39
023	Concentration (μg/m^3)	97.9	59.9	59.3	58.0	54.9	50.6	49.9	49.1	48.8	44.7
	Date/Time	12/21	8/20	8/20	8/20	8/20	1/1	1/1	1/1	1/1	1/1
		1:55	4:15	5:20	6:25	7:30	14:30	11:35	17:75	15:50	20:50
	Wind Speed (mph)	6	2	1	2	2	5	6	6	4	8
	Wind Direction	158	171	186	178	94	17	340	261	292	178
024	Concentration (μg/m^3)	128.5	56.4	54.3	54.1	51.7	50.8	50.8	49.5	49.1	44.7
	Date/Time	12/10	5/2	1/5	5/2	12/10	3/3	3/4	5/2	4/13	3/3
		6:20	3:20	11:50	4:25	7:25	22:50	0:05	5:30	17:35	20:35
	Wind Speed (mph)	0	1	11	2	0	4	4	2	3	1
	Wind Direction	4	97	173	91	54	62	55	111	306	50

Table IV-17

TEN HIGHEST TWENTY-FOUR HOUR PARTICULATE AVERAGES

Site		1	2	3	4	5	6	7	8	9	10
020	Concentration ($\mu g/m^3$)	113.0	89.0	70.0	69.0	62.0	59.0	49.0	48.0	47.0	46.0
	Date	11/29	4/25	5/20	5/4	10/12	10/7	8/29	6/18	7/12	4/26
021	Concentration ($\mu g/m^3$)	125.0	97.0	87.0	81.0	77.0	75.0	71.0	64.0	62.0	51.0
	Date	4/25	5/20	10/7	9/1	5/4	6/19	11/21	4/26	10/12	6/25
022	Concentration ($\mu g/m^3$)	154.0	116.0	82.0	80.0	70.0	70.0	69.0	68.0	60.0	55.0
	Date	11/28	12/1	4/25	5/20	10/7	10/12	7/24	5/4	9/24	6/18
023	Concentration ($\mu g/m^3$)	171.0	112.0	107.0	81.0	67.0	65.0	62.0	61.0	57.0	56.0
	Date	3/22	4/25	5/20	10/7	5/16	6/17	6/18	10/12	4/6	6/19
024	Concentration ($\mu g/m^3$)	178.0	162.0	86.0	80.0	80.0	75.0	69.0	56.0	52.0	46.0
	Date	11/27	11/29	5/20	4/25	10/12	10/6	5/4	4/26	6/18	6/19

Table IV-18 MONTHLY AVERAGE AMBIENT AIR CONSTITUENT CONCENTRATIONS OF GASES AND PARTICULATES ($\mu g/m^3$)

1974-1975

Trailer	Item	Month: Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
020	NO ($\mu g/m^3$)	1.9	0.7	3.4	*0.4	*0.3	9.6	17.8	*3.2	*0.4	9.1	*3.2	3.5
023		4.4	*12.8	14.7	0.4	*1.2	0.6	0.1	0.3	0.6	1.4	0.6	0.3
020	NO_2 ($\mu g/m^3$)	2.8	6.8	4.5	*2.5	*1.2	2.7	4.1	*0.3	*1.7	4.7	*3.0	7.9
023		2.4	*4.7	7.4	0.2	*0.4	0.9	0.5	0.0	1.5	1.0	0.1	0.7
020	O_3 ($\mu g/m^3$)	58.0	69.3	93.7	105.1	88.0	77.1	71.5	69.1	74.6	50.8	41.1	32.8
023		*31.4	28.0	42.4	85.8	85.6	90.5	87.3	84.4	86.1	61.0	53.4	43.3
020	Non-Methane H.C. ($\mu g/m^3$)	73.4	97.4	*75.7	23.4	38.6	327.6(2)	38.9	50.8	25.8	27.9	58.9	75.9
023		933.0(1)	20213.6(1)	*662.8(1)	22.1	*17.1	49.1	43.3	196.5	220.2	145.6	92.2	331.8
020	CH_4 ($\mu g/m^3$)	826.1	918.8	*908.1	879.4	829.8	590.6(2)	833.6	821.2	825.9	908.8	949.3	935.6
023		825.5	1053.8(1)	*943.6(1)	*833.7	*859.8	836.3	834.3	814.7	780.7	902.7	933.4	814.1
020	CO ($\mu g/m^3$)	553.8	676.9	908.2	1228.5(2)	1498.0(2)	*853.0(2)	1815.5(2)	1092.1(2)	206.5(2)	(4)	(4)	(4)
023		3703.6(1)	2439.3(1)	1786.2(1)	391.4	504.5	485.8	699.9	437.0	468.5			
020	SO_2 ($\mu g/m^3$)	0	1.8	0	0.1	1.1	0.1	0	1.0	1.6	0.9	0.7	1.4
021		1.3	1.7	0.8	0.8	0.6	1.2	1.1	2.1	1.3	1.9	1.7	1.8
022		2.6	0.1	0	0.2	0	0	0.5	1.7	0.4	0.6	0	0.6
023		0	6.4	3.3	0.1	0.6	0.5	0	0.0	0.6	2.0	0.9	0.2
024		0.2	1.7	1.3	5.5	0.9	1.1	0.7	0.6	0.1	0.9	0.7	2.0
020	H_2S ($\mu g/m^3$)	0	0	0	0	0.4	0	0	0.2	0	0	0.1	0.1
021		1.6	0	0.2	0.8	0.4	0.2	0.4	0.7	0.2	0.4	0.7	0.8
022		0.2	1.2	0	0.2	0.3	0.7	0	0.4	0.2	0.3	0.4	0.2
023		0	5.2	2.5	0.7	2.7	0.5	0.3	0.3	4.8	2.4	2.1	0
024		0	0.1	0	0.2	0.4	1.0	0.3	1.1	0.1	0.1	0.6	1.0
020	Particulate ($\mu g/m^3$)	*48.7(3)	4.3	3.3	3.8	6.5	11.6	12.4	10.7	14.7	18.6	12.8	11.2
021		*20.4	5.4	4.0	4.5	6.9	13.7	13.2	12.3	15.6	14.3	12.4	12.4
022		*35.3	4.2	2.9	3.2	5.3	11.9	11.2	9.5	14.6	11.5	12.6	9.7
023		*18.0	*6.8	*2.5	4.2	11.5	15.4	19.3	18.3	14.4	11.7	11.1	13.7
024		*117.0	2.9	2.3	3.8	4.9	10.2	11.4	8.7	11.3	10.6	9.8	12.4

* 50% Or Less Data

(1) Reported data are incorrect because of contaminated manifold.

(2) Reported data may be incorrect because of possible malfunctioning instrument.

(3) Very few particulate data points available for November 1974. The values reported were unduly influenced by the occurrence of a few unusually high 24-hour concentrations.

(4) Data to be reported at later date

Table IV-19 TRACT MAXIMUM GAS CONCENTRATIONS ($\mu g/m^3$)
1974-1975

Trailer	Item	Averaging Time (Hr.)	Month											
			Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
020	NO	1	44.3	16.4	43.7	7.8	4.7	27.1	34.0	29.8	3.1	38.1	26.5	34.2
023	NO	1	38.5	93.9	114.2	52.6	16.7	10.1	4.2	28.7	15.3	17.0	16.5	9.0
020	NO_2	1	26.7	36.0	17.6	14.4	11.2	16.7	17.0	20.8	33.9	12.4	9.1	20.2
023	NO_2	1	21.2	47.0	68.2	9.2	4.8	10.1	8.0	3.7	13.2	59.9	9.3	7.6
020	O_3	1	108.1	117.9	130.9	146	146.2	115.3	124.5	160.4	130.9	114.0	80.8	56.2
023	O_3	1	64.6	68.5	97.7	136	145.9	116.1	139.5	152.2	129.9	127.0	135.3	58.0
020	Non-Methane H.C.	3 (6-9 A.M.)	197.6	179.7	223.8	51.4	288.6	707.7(2)	83.5	141.2	69.6	42.1	319.4	486.9
023	Non-Methane H.C.	3 (6-9 A.M.)	(1)	(1)	(1)	18.1	34.2	302.2	120.0	355.1(2)	895.6(2)	520.4	349.6	533.2
020	CH_4	3 (6-9 A.M.)	933.2	1219.5	999.2	1298.0	998.8	837.8	924.0	862.5	859.2	1009.0	1068.1	1342.9
023	CH_4	3 (6-9 A.M.)	(1)	(1)	(1)	900.1	910.2	902.4	903.9	879.1	879.4	979.5	1029.5	964.3
020	CO	1	1353.8	1853.7	1700.8	1716.6(2)	3680.4(2)	1811.5(2)	3296.9(2)	4650.9(2)	2065.3(2)	(3)	(3)	(3)
023	CO	1	(1)	(1)	(1)	769.7	2421.1	740.9	1155.9	790.8	1635.9			
020			4.6	17.4	2.6	7.6	32.8	7.2	7.6	20.8	33.9	12.4	9.1	20.2
021			32.8	25.8	53.4	23.2	21.3	21.7	34.3	67.9	18.2	16.9	11.3	20.8
022	SO_2	1	13.0	20.8	5.9	11.7	14.1	2.6	18.2	27.4	14.5	16.3	2.4	13.0
023			0.2	97.9	50.6	5.0	12.2	8.2	7.2	3.7	13.2	59.9	9.3	7.6
024			5.2	128.5	54.3	34.3	50.8	49.1	56.4	33.0	10.6	26.5	20.6	41.7
020			10.1	2.2	6.2	13.7	12.5	2.2	1.2	21.7	2.9	5.9	1.7	2.1
021			58.9	4.6	4.7	9.5	7.3	4.3	9.0	13.8	3.5	8.3	6.9	13.8
022	H_2S	1	4.7	8.4	2.4	14.3	14.1	10.1	1.3	11.9	5.7	4.3	3.8	11.9
023			3.2	45.3	28.4	8.2	19.1	6.5	6.9	8.0	71.2	38.5	15.1	1.8
024			8.3	7.7	27.6	8.1	8.5	62.5	56.9	70.9	3.0	8.5	10.4	20.9

(1) Reported data incorrect due to manifold contamination
(2) Reported data may be incorrect because of possible malfunctioning instrument.
(3) Data to be reported at later date

reports for a full explanation of the threshold limits and the significance of the reported data below the five parts-per-billion-by-volume detection threshold limit.) These detection threshold limits are equivalent to 13 micrograms per cubic meter (ug/m^3) for SO_2 and 7 ug/m^3 for H_2S. Ambient concentrations of sulfur dioxide have also been determined on a spot-check basis using the West-Gaeke, wet-chemical method. This analytical method has shown that a number of ambient concentrations of SO_2 were below the four-micrograms-per-cubic-meter, detection, threshold limit of this method at the time when measurements were taken. The global-average, background concentrations for SO_2 are one to four ug/m^3 and for H_2S are three-tenths ug/m^3.

As can be seen from the detailed data presented in the monthly data reports and the monthly one-hour maximums summarized in Table IV-19, relatively high ambient-air hydrogen sulfide and sulfur dioxide concentrations have been measured frequently at all air quality stations. These short term peaks suggest the presence of source(s) near the Tract. Attempts to correlate the concentrations with wind direction have not indicated any patterns which would help identify the source.

It is known that the Tract is virtually surrounded by natural-gas, production operations and that hydrogen sulfide can occur in conjunction with natural gas. H_2S can undergo rapid oxidation to S_2O after its release into the atmosphere. These near-by gas operations may be a potential source for H_2S, the primary pollutant (i.e., emitted directly into the air), which would subsequently be oxidized in the atmosphere to SO_2, the secondary pollutant (i.e., formed by atmospheric chemical reactions from primary pollutants). Therefore, it would be reasonable to assume that, under certain meteorological conditions, a similar correlation for these two gases with wind direction would be observed.

Figure IV-5 illustrates daily H_2S and SO_2 averages for a twelve-month period at Stations 021 and 023. It can be seen in these plots that detectable H_2S and SO_2 concentrations frequently occur simultaneously. Figures IV-6 and IV-7 display a degree of similarity in the patterns of H_2S and SO_2 concentrations as correlated with wind direction and wind speed. The similarity in these patterns is most noticeable at Station 023 and could be interpreted as evidence that H_2S is the SO_2 precursor.

Daily concentration averages for the first year of baseline (Figures IV-6 and IV-7) show a higher frequency of detectable H_2S concentration occurring on the plateau at Station 023. The annual averages reported in Tables IV-11 to IV-15 also indicate a higher, annual average, H_2S concentration at Station 023. The highest frequency of occurrence for detectable S_2O concentrations was recorded at Station 021, the furthest downstream valley station in the air quality network. The annual average for SO_2 is highest at Stations 021 and 024 followed by Station 023. The lowest annual averages and the lowest frequencies of occurrence for the two gases occur at the valley Stations 020 and 022.

Ozone (O_3) is considered to have a global average, background level of between 40 and 80 ug/m^3. Ozone as a constituent of the urban atmosphere

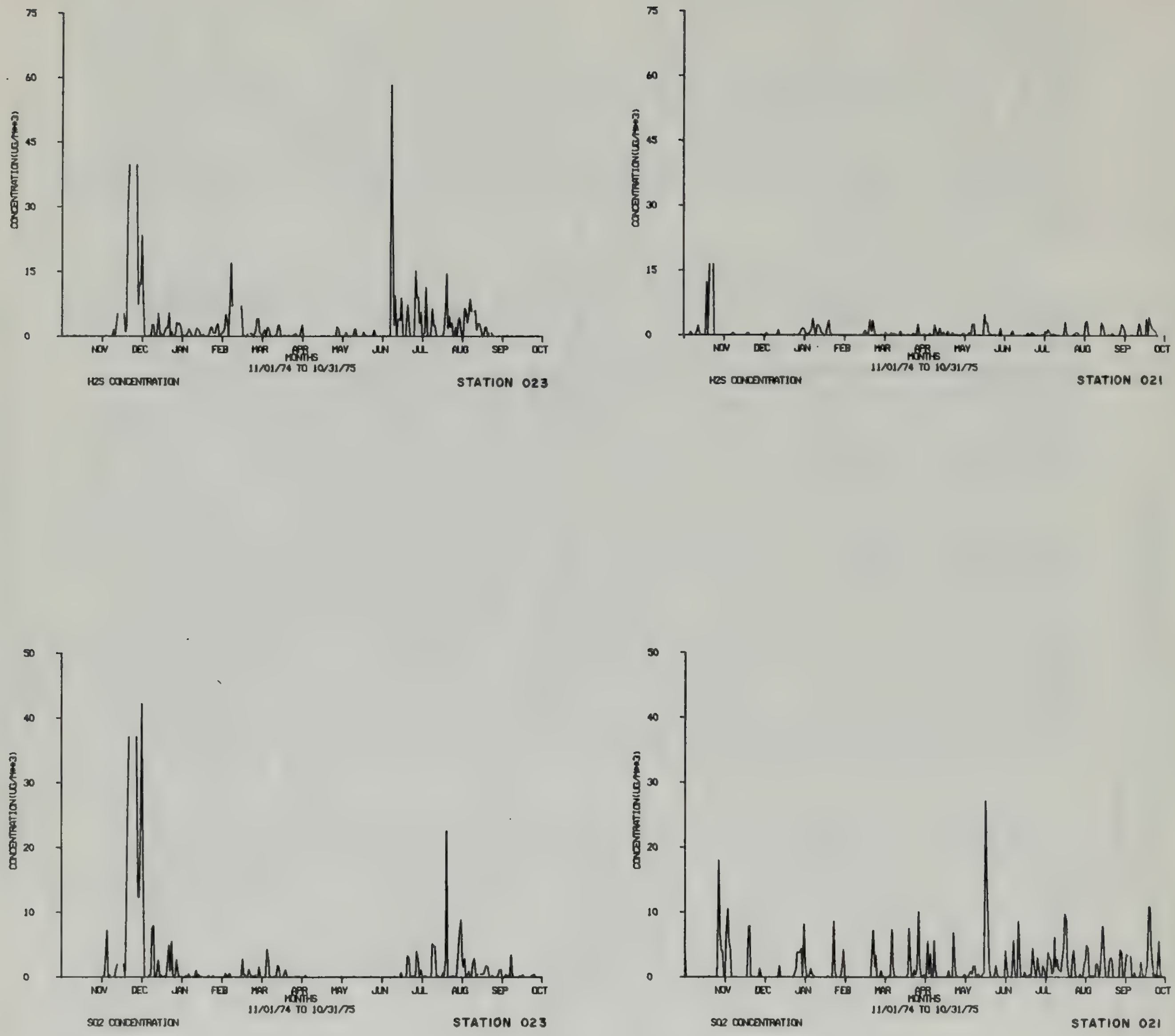
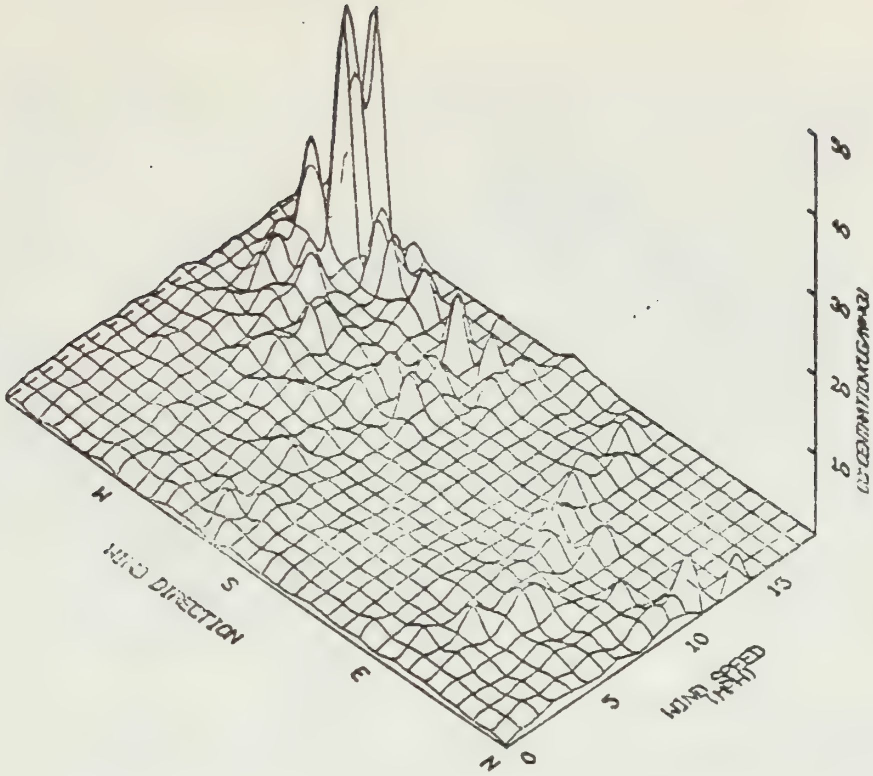
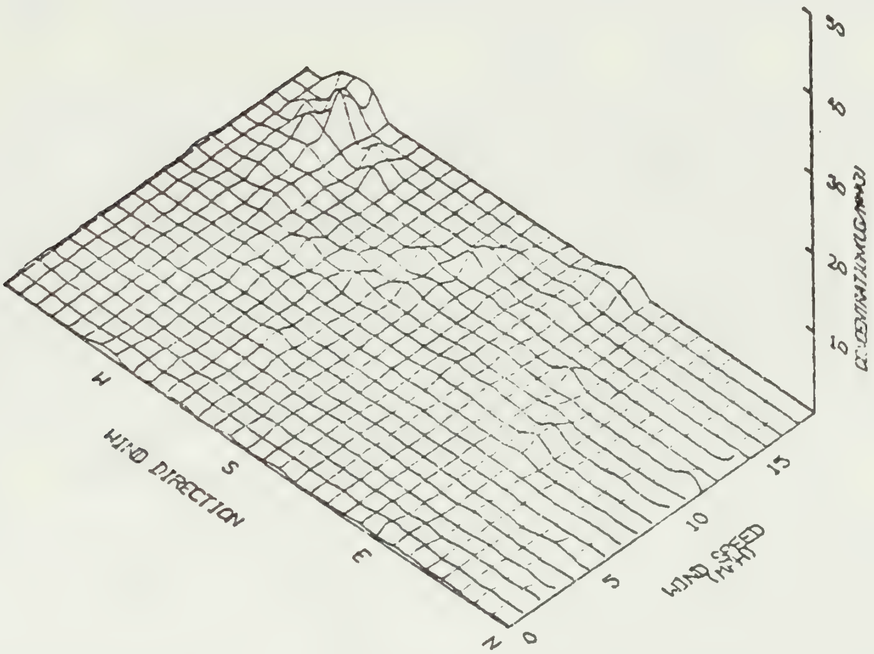


Figure IV-5 TWELVE MONTH PLOTS OF DAILY SO_2 & H_2S CONCENTRATION AT STATIONS 021 & 023

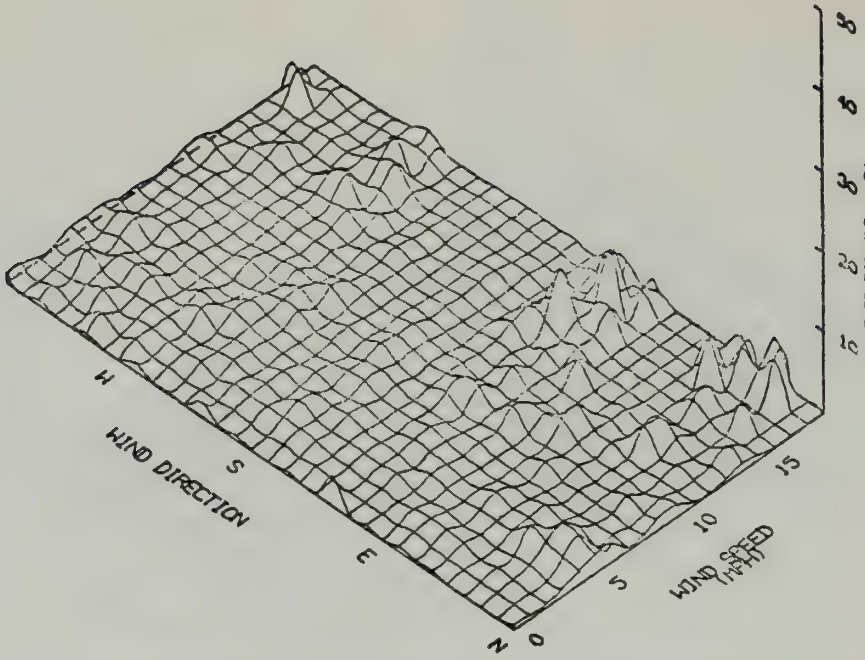


SO_2 CONCENTRATION AT STATION 021 NOV. 1974 THRU OCT. 1975

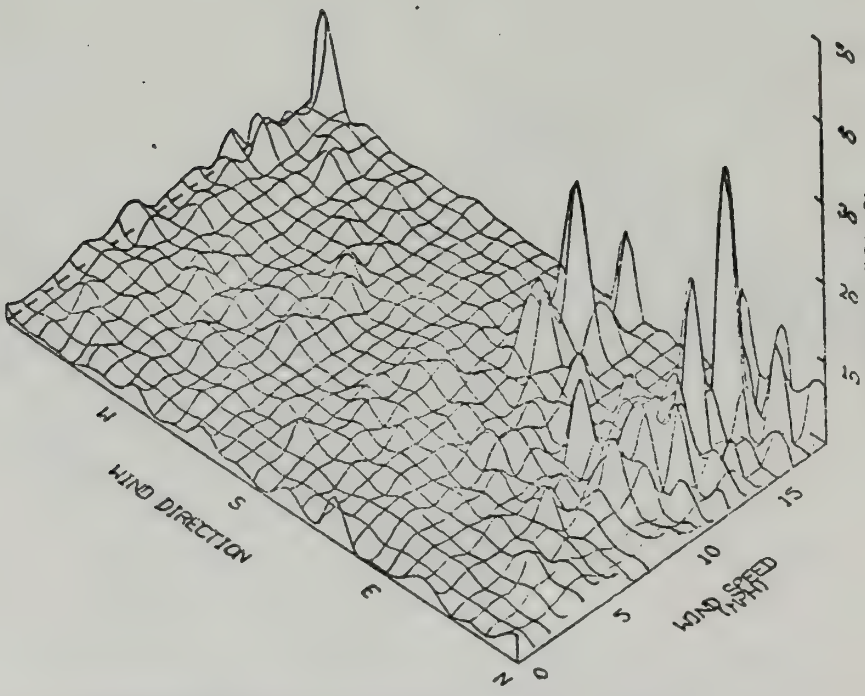


H_2S CONCENTRATION AT STATION 021 NOV. 1974 THRU OCT. 1975

Figure IV-6 THREE DIMENSIONAL PLOTS CORRELATING SO_2 & H_2S CONCENTRATIONS AT STATION 021 WITH WIND SPEED AND DIRECTION



SO_2 CONCENTRATION AT STATION 023 NOV. 1974 THRU OCT. 1975



H_2S CONCENTRATION AT STATION 023 NOV. 1974 THRU OCT. 1975

Figure IV-7 THREE DIMENSIONAL PLOTS CORRELATING SO_2 & H_2S CONCENTRATIONS AT STATION 023 WITH WIND SPEED AND DIRECTION

is a secondary pollutant, i.e., it is not emitted into the atmosphere as such but is the result of atmospheric reaction involving other emitted pollutants--primarily hydrocarbons and nitrogen oxides in a photochemically-induced reaction. Both the absolute concentrations of these precursors and their concentration ratios are important. Sunlight intensity and duration and temperature are among the more important factors which can influence the production of ozone. Moreover, stagnation can provide favorable conditions for ozone formation by allowing the buildup of the precursors and prolonging the period of time in which the reactions can occur.

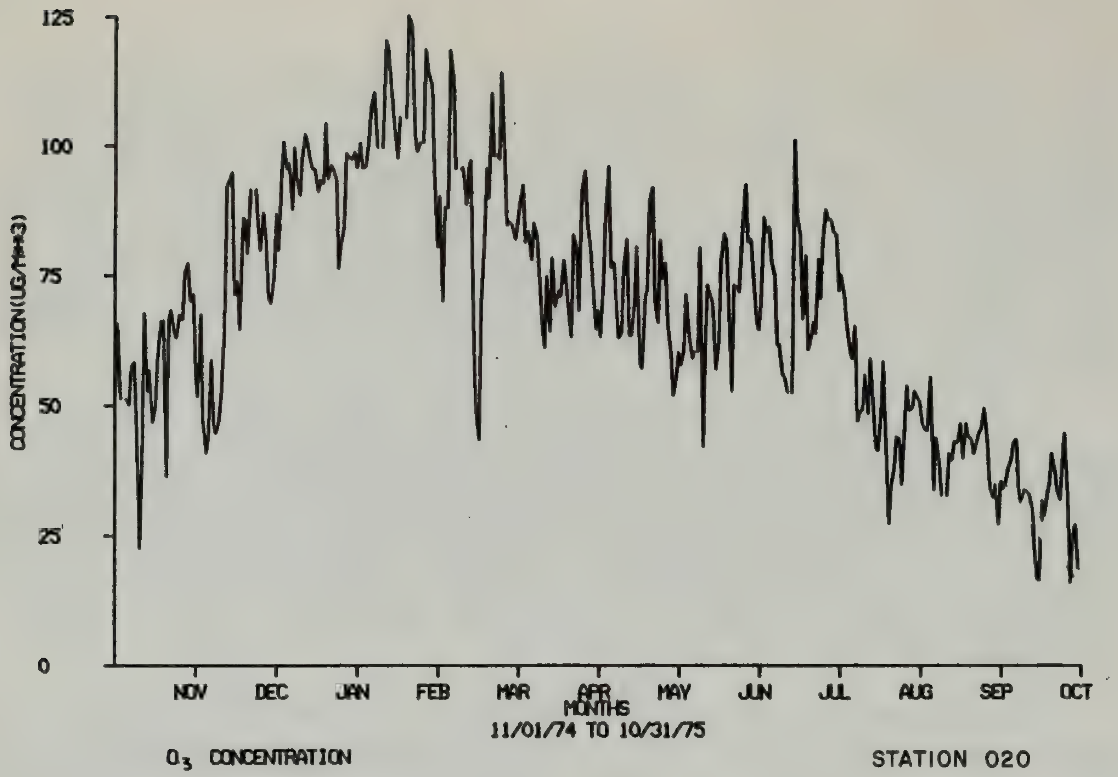
In addition to the possibility that ozone levels at the Tract are influenced by the photochemical reactions involving both anthropogenic and naturally occurring hydrocarbons and oxides of nitrogen, transport from the stratosphere may also influence the ground level ozone concentrations. This process may play an important role in the observed seasonal variations of ozone at the tract. Stratospheric ozone transport would tend to cause higher ozone concentrations during the spring and summer and lower concentrations during the fall and winter.

Annual average ozone levels on the Tract of about 69 ug/m^3 are reported in Tables IV-11 and IV-14 for Stations 020 and 023, respectively. These levels tend towards the upper range of the normal ozone background levels found in rural, unpolluted areas. The one-hour maximum ozone concentration is 160 ug/m^3 as shown in Table IV-18. As can be seen, relatively high ozone values occur with some regularity on the Tract and in the Piceance Creek valley. Similarly, the occurrence of high ozone concentrations in rural areas has been documented on numerous occasions by various air monitoring networks throughout the nation.

Daily average ozone concentration plots for the twelve-month period are presented in Figure IV-8 for Stations 020 and 023. These graphs illustrate a very obvious seasonal trend with the higher ozone concentrations occurring from the late winter months through the mid-summer months and lower concentrations occurring from the late summer months through the mid-winter months.

Diurnal bar graphs for ozone have appeared in previous quarterly data reports. These have consistently shown a distinct diurnal peak occurring in the daylight hours. Examples of the diurnal ozone concentration variations are given in Figure IV-9. These are the quarterly composites for Station 020 and illustrate the fact that peak magnitude occurs during peak solar insolation and that peak width varies with season.

This well-defined diurnal ozone cycle is similar to the trend observed for photochemical oxidant formation in a polluted urban atmosphere. It does not seem probable that such a cycle and the resulting higher ozone levels could be caused by ozone transport or transportation of ozone precursors from urban areas. It further seems improbable that stratospheric transport of ozone alone would produce these consistent diurnal cycles. Natural sources of ozone, possibly as a result of photochemically induced reactions involving naturally occurring hydrocarbons, may provide a more plausible explanation.



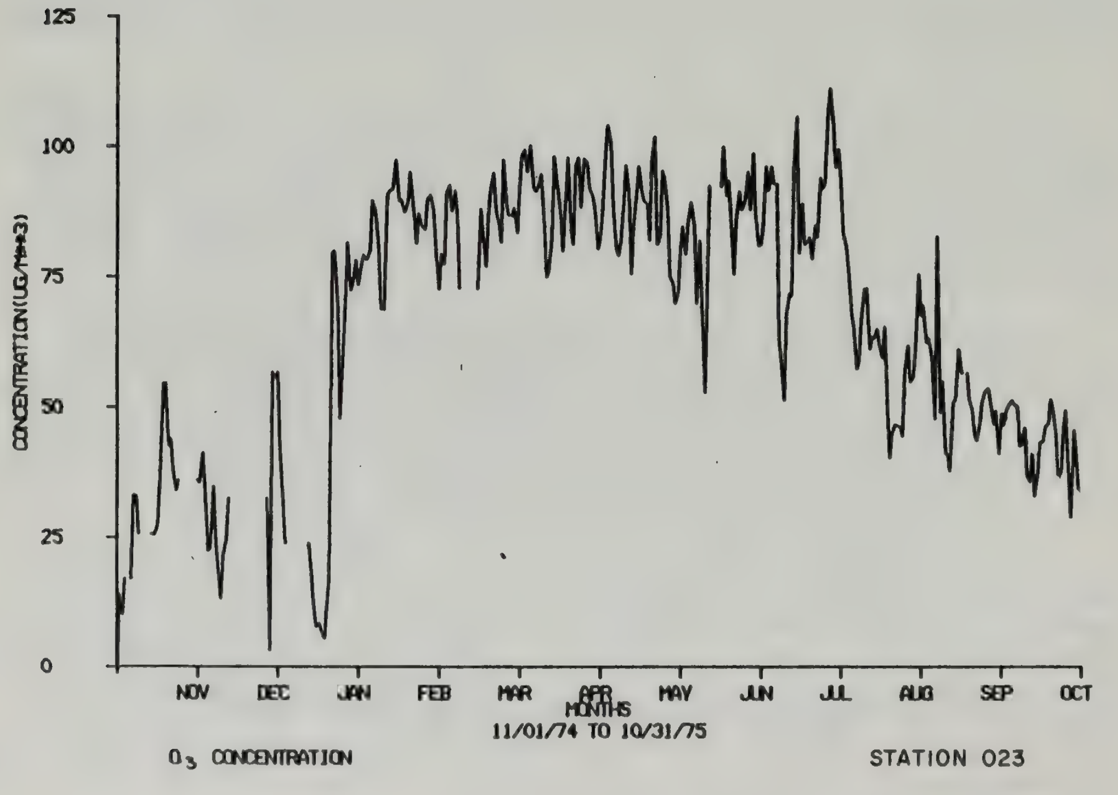


Figure IV-8 TWELVE MONTH PLOTS OF THE DAILY OZONE CONCENTRATION AT STATIONS 020 AND 023

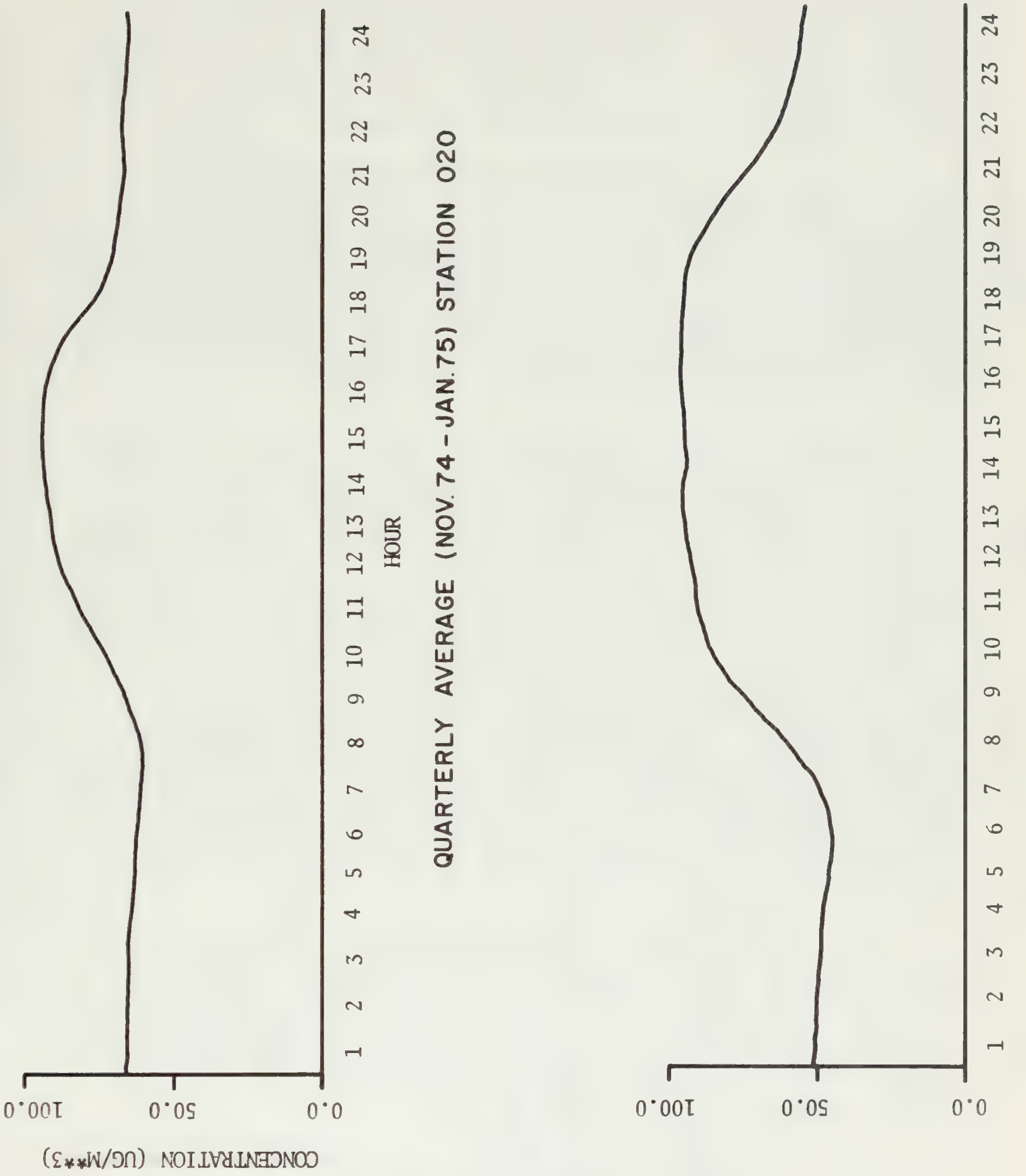


Figure IV-9 QUARTERLY COMPOSITE OF THE DIURNAL OZONE AT STATION 020

The global-average-background carbon monoxide (CO) concentration is 100-200 ug/m^3. It can be seen from the long term annual (Table IV-11 and IV-14) and monthly averages (Table IV-11) that the Tract carbon monoxide levels are considerably above this and imply that the regional atmospheric concentrations are also well above the background concentration. The short-term, monthly, one-hour maximums in Table IV-19 indicate a nearby source and are undoubtedly influenced by automobile traffic on the Tract and in the Piceance Creek valley. The fact that the higher traffic along the valley road contributes to the CO levels in the valley can be seen in the higher, annual average reported for Station 020.

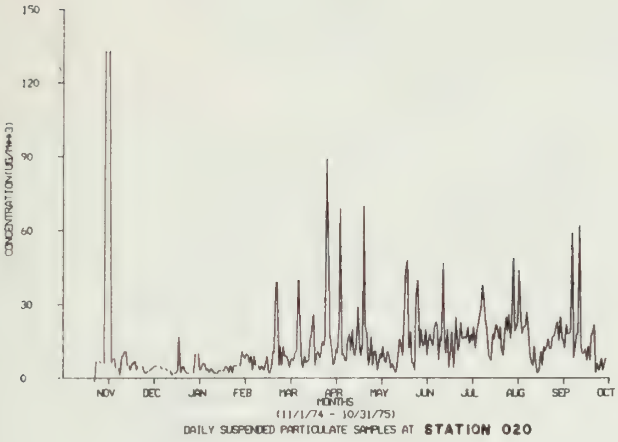
The ambient air concentrations of oxides of nitrogen (NO_x, NO, NO_2), as reported in Tables IV-11 and IV-14 for the annual average and Table IV-18 for the monthly averages, indicate that concentrations frequently occur above the global-average-background levels of 0.25-2.15 ug/m^3 for nitric oxide (NO) and 1.9-2.6 ug/m^3 for nitrogen dioxide (NO_2). The data do not indicate any obvious trends or patterns but these gases are known to be emitted by automobiles as well as other combustion processes. The influence of the traffic along the Piceance Creek valley road can surmized from the higher annual averages recorded at the valley Station 020 for the oxides of nitrogen.

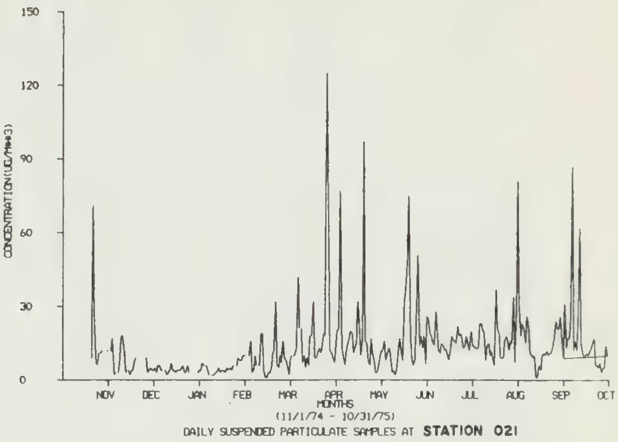
The annual averages for methane (CH_4) (Tables IV-11 and IV-14 for Stations 020 and 023, respectively) and the monthly averages (Table IV-18) are in agreement with the global-average-background range of 814-977 ug/m^3. The non-methane hydrocarbon (NMHC) 6:00-9:00 a.m. maxima (Table IV-19), the annual averages (Tables IV-11 and IV-14) and monthly average (Table IV-18) show much greater variation than the methane concentrations. The differences between the Piceance Creek valley and plateau sites are often substantial. Considerable caution is urged in the interpretation of these data. EPA tests have shown that the precision and reliability of NMHC measurement determined by subtractive gas chromatography is poor. With this in mind, the data for Station 023 located on the Tract seem to indicate increasingly higher NMHC concentrations from June through October. (This is graphically illustrated in Quarterly Data Report #5). This trend may, in part, be caused by the volatilization of naturally occurring organic compounds as a result of the seasonally warmer temperatures and increased vegetation growth at that time of the year. Further data collection and analyses may substantiate this interpretation. The automobile traffic in the area is yet another source of hydrocarbons and undoubtedly affects the ambient air concentration.

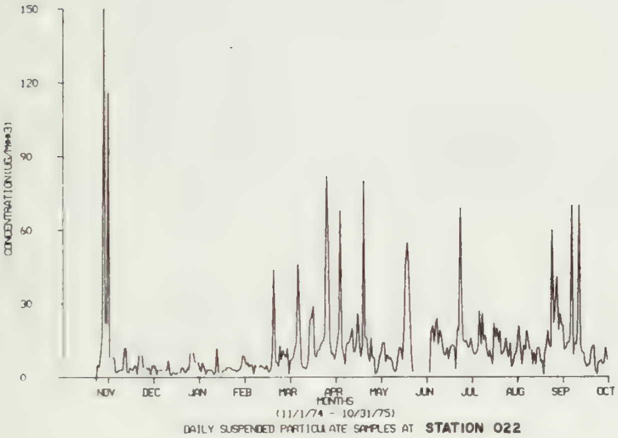
The annual and monthly concentration averages for particulates are reported in Tables IV-11 to IV-15 and Table IV-11, respectively. The monthly average ambient concentrations of particulates seem to exhibit a seasonal trend. Figure IV-10 illustrates the 24-hour, particulate-concentration variation for a twelve-month period at each station. The lowest concentrations occur during the winter months when the snow cover, lower wind speeds and decreased level of activity in the area tend to reduce the amount of fugitive dust.

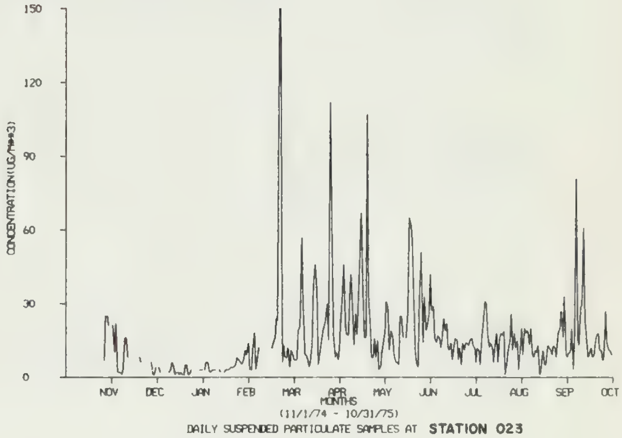
Wind speeds affect the ambient particulate concentrations and higher particulate filter loadings often result as persistent wind

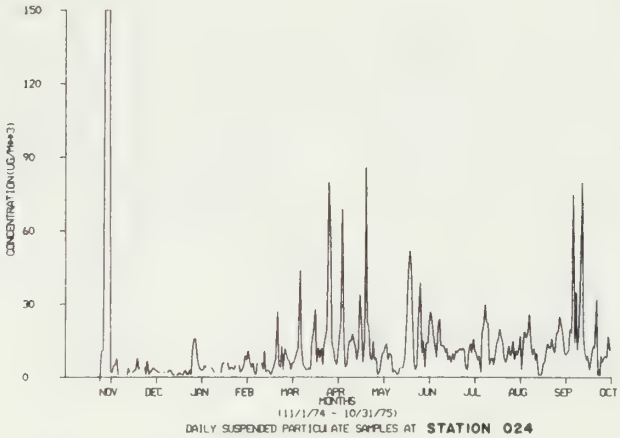
Figure IV-10 TWELVE MONTH PLOTS OF THE 24-HOUR PARTICULATE CONCENTRATION FOR EACH OF THE FIVE STATIONS











speeds reach 10-15 mph. Results based on twelve months of particulate concentration data, however, indicate that other factors play as great a role in affecting the ambient particulate concentrations. Soil moisture may well be the single most important factor influencing the first year baseline particulate data. Other factors affecting particulate concentrations are fugitive dust from open fields, construction activity, traffic over dirt roads, agricultural activities in the valley and naturally occurring organic aerosols which may be present.

Special cellulose filters having low background levels of trace element content have been utilized every sixth day at Station 023. These filters were combined into a composite sample once each quarter and analyzed to determine average ambient-air concentrations of trace elements and radioactivity levels. The composite trace element concentrations are shown in Table IV-20. Spot check samples using a single filter were used to detect any gross short-term variations from the average. These data are shown in Table IV-21. The volatile trace metals, i.e., selenium, mercury and arsenic (analyzed as arsine, AsH^3), were collected and analyzed once each quarter by specialized techniques. The results are reported in Table IV-22. The ambient-air, trace-element levels reported to date have been quite low. Further quantitative analysis would have been performed if high levels of toxic elements had been detected, or if beta radiation exceeded one picocurie per cubic meter, or if large increases in gross radioactivity had occurred. Radioactivity levels shown in Table IV-23 are well below the one picocurie-per-cubic-meter level and can be considered as normal background levels.

Particulate mass distributions by aerodynamic size range have been determined once each quarter using an Andersen high-volume cascade-impactor sampler. These data are reported in Table IV-24. The data may provide an additional assessment of development-related and operation-related impacts.

An area-wide visibility study began on September 27, 1975. The contractor's first quarterly report covers the period through November 1975 and is completely reported in Quarterly Data Report #5. An abridged version of that report is presented in Summary Report #5.

A complete annual report of this study will be presented in the second annual report at the completion of the second year of the baseline program.

TABLE IV-20
AMBIENT CONCENTRATIONS OF TRACE ELEMENTS ON TRACT C-b
Composite Samples
Concentrations in ug/m^3

	Composite Nov.-Dec. 1974	Composite Jan. - March 1975	Composite April-June 1975	Composite
Uranium	$7x10^{-5}$	$2x10^{-3}$	$2x10^{-4}$	
Thorium	$6x10^{-5}$		$3x10^{-4}$	
Bismuth	$2x10^{-5}$	$1x10^{-4}$	$2x10^{-4}$	
Lead	$3x10^{-3}$	$2x10^{-3}$	$5.8x10^{-3}$	
Thallium				
Mercury	$2x10^{-5}$	$2x10^{-8}$	$2x10^{-4}$	
Gold				
Platinum				
Iridium				
Osmium				
Rhenium		Internal Standard	Internal Standard	
Tungsten	$4x10^{-5}$		*	
Tantalum				
Hafnium				
Lutecium				
Ytterbium				
Thullium				
Erbium				
Holmium				
Dysprosium				

	Composite Nov.-Dec. 1974	Composite Jan. - March 1975	Composite April-June 1975	Composite
Terbium				
Gadolinium			$1x10^{-5}$	
Europium			$2x10^{-5}$	
Samarium			$2x10^{-4}$	
Neodymium	$4x10^{-4}$	$1x10^{-4}$	$5x10^{-4}$	
Praseodymium	$3x10^{-5}$	$2x10^{-5}$	$2x10^{-4}$	
Cerium	$1x10^{-4}$	$1x10^{-4}$	$4x10^{-3}$	
Lanthanum	$9x10^{-5}$	$5x10^{-5}$	$1x10^{-3}$	
Barium	$1x10^{-3}$	$1x10^{-3}$	$2.9x10^{-2}$	
Cesium	$7x10^{-5}$		$1x10^{-4}$	
Iodine			$8x10^{-5}$	
Tellurium				
Antimony	$5x10^{-5}$	$8x10^{-5}$	$8x10^{-5}$	
Tin	$6x10^{-4}$	$2x10^{-4}$	$2x10^{-4}$	
Indium		Internal Standard	Internal Standard	
Cadmium			$2x10^{-4}$	
Silver	$6x10^{-4}$	$2x10^{-5}$	$2x10^{-5}$	
Palladium				
Rhodium				
Radium	10^{-15}	10^{-15}	10^{-14}	

	Composite Nov.-Dec. 1974	Composite Jan.-March 1975	Composite April-June 1975	Composite
Ruthenium				
Molybdenum	$2x10^{-4}$		*	
Niobium	$6x10^{-5}$		$2x10^{-3}$	
Zirconium	$3x10^{-4}$		$3.8x10^{-3}$	
Yttrium	$1x10^{-4}$	$1x10^{-4}$	$5x10^{-4}$	
Strontium	$3x10^{-3}$	$2x10^{-4}$	$1.2x10^{-2}$	
Rubidium	$2x10^{-3}$	$9x10^{-4}$	$5x10^{-4}$	
Bromine		$1x10^{-4}$	$2x10^{-5}$	
Selenium	$8x10^{-7}$	$6x10^{-5}$	$4x10^{-5}$	
Arsenic	$1x10^{-4}$	$1x10^{-3}$	$3x10^{-4}$	
Germanium	$3x10^{-5}$	$3x10^{-5}$	$4x10^{-5}$	
Gallium	$1x10^{-4}$	$1x10^{-5}$	$1x10^{-4}$	
Zinc	$1x10^{-2}$	$9x10^{-3}$	*	
Copper	$9x10^{-3}$	$6x10^{-2}$	$1.3x10^{-2}$	
Nickel	$4x10^{-4}$	$3x10^{-4}$	*	
Cobalt	$3x10^{-4}$		$3x10^{-4}$	
Iron	$3x10^{-2}$	2.6	0.81	
Manganese	$3x10^{-3}$	$7x10^{-2}$	$8.1x10^{-3}$	
Chromium	$7x10^{-4}$		$4.3x10^{-3}$	

	Composite Nov.-Dec. 1974	Composite Jan.-March 1975	Composite April-June 1975	Composite
Vanadium	$4x10^{-4}$	$2x10^{-4}$	$9x10^{-4}$	
Titanium	$4x10^{-3}$	$6x10^{-3}$	$9.6x10^{-2}$	
Scandium			$2x10^{-4}$	
Calcium	.3	.44	1.2	
Potassium	.1	.26	0.20	
Chlorine	$1x10^{-3}$		*	
Sulphur	$7x10^{-3}$	$6x10^{-2}$	$8.5x10^{-2}$	
Phosphorus	$3x10^{-3}$	$4.2x10^{-2}$	$6.5x10^{-2}$	
Silicon		.42	1.2	
Aluminum	.1	$2x10^{-2}$	0.31	
Magnesium	.2	3.6	0.13	
Sodium	$5x10^{-2}$	4.2	0.14	
Fluorine	$1x10^{-2}$		*	
Oxygen		NR	NR	
Nitrogen		NR	NR	
Carbon		NR	NR	
Boron	$2x10^{-2}$		NR	
Beryllium	$2x10^{-7}$		$3x10^{-5}$	
Lithium	$1x10^{-4}$		$3.1x10^{-3}$	

NOTE: NR--Not reported
When no number appears, concentration is less than $1x10^{-5}$ ug/m^3

*Unable to determine because of blank level.

TABLE IV-21
TRACE ELEMENT ANALYSIS OF SINGLE FILTER SAMPLES ON TRACT C-b
Concentrations in ug/m^3

	Single Filter Sample 12/4/74	Single Filter 1/28/75	Single Filter 4/24/75	Single Filter
Uranium	5x10^{-5}		1x10^{-4}	
Thorium	3x10^{-5}		2x10^{-4}	
Bismuth	3x10^{-5}	1x10^{-3}	2x10^{-4}	
Lead	1x10^{-2}		1.2x10^{-2}	
Thallium				
Mercury	1x10^{-5}	2x10^{-8}	2x10^{-4}	
Gold				
Platinum				
Iridium				
Osmium				
Rhenium	Internal Standard		Internal Standard	
Tungsten	3x10^{-5}		2x10^{-6}	
Tantalum				
Hafnium				
Lutecium				
Ytterbium				
Thullium				
Erbium				
Holmium				
Dysprosium				

	Single Filter Sample 12/4/74	Single Filter 1/28/75	Single Filter 4/24/75	Single Filter
Terbium				
Gadolinium				
Europium				
Samarium				
Neodymium	9x10^{-5}		1x10^{-4}	
Praseodymium	7x10^{-5}		2x10^{-4}	
Cerium	5x10^{-4}	1x10^{-4}	1.5x10^{-3}	
Lanthanum	2x10^{-4}	1x10^{-4}	1.7x10^{-3}	
Barium	2x10^{-3}	2x10^{-3}	1.5x10^{-2}	
Cesium	1x10^{-4}			
Iodine		8x10^{-4}	7x10^{-5}	
Tellurium	4x10^{-5}			
Antimony	2x10^{-4}	5x10^{-5}	1x10^{-4}	
Tin	2x10^{-3}	2x10^{-4}	2x10^{-4}	
Indium		Internal Standard	Internal Standard	
Cadmium	8x10^{-7}	2x10^{-4}	1x10^{-4}	
Silver	1x10^{-4}		2x10^{-5}	
Palladium				
Rhodium				
Radium	<10^{-15}	<10^{-15}	<10^{-15}	

	Single Filter Sample 12/4/74	Single Filter 1/28/75	Single Filter 4/24/75	Single Filter
Ruthenium				
Molybdenum	5x10^{-4}	1x10^{-3}	*	
Niobium	7x10^{-5}	2x10^{-5}	1.2x10^{-3}	
Zirconium	1x10^{-3}	[illegible]x10^{-5}	3.1x10^{-3}	
Yttrium	2x10^{-4}	2x10^{-4}	4x10^{-4}	
Strontium	6x10^{-3}	5x10^{-3}	1.3x10^{-2}	
Rubidium	4x10^{-3}	2x10^{-4}	6x10^{-4}	
Bromine	7x10^{-5}	7x10^{-4}	4x10^{-4}	
Selenium	8x10^{-5}	1x10^{-4}	4x10^{-4}	
Arsenic	7x10^{-4}	2x10^{-3}	3x10^{-4}	
Germanium		2x10^{-5}	4x10^{-5}	
Gallium	5x10^{-4}	2x10^{-5}	1x10^{-4}	
Zinc	2x10^{-2}	3x10^{-3}	*	
Copper	2x10^{-2}	2x10^{-3}	3.1x10^{-3}	
Nickel	3x10^{-4}	4x10^{-4}	2x10^{-4}	
Cobalt	4x10^{-4}		2x10^{-4}	
Iron	7x10^{-2}	1.6	≈0.81	
Manganese	1x10^{-2}	5x10^{-2}	1.1x10^{-2}	
Chromium	1x10^{-3}		6x10^{-4}	

	Single Filter Sample 12/4/74	Single Filter 1/28/75	Single Filter 4/24/74	Single Filter
Vanadium	2x10^{-3}	5x10^{-4}	2.1x10^{-3}	
Titanium	9x10^{-3}	1.4x10^{-2}	0.11	
Scandium			1x10^{-4}	
Calcium	1.1	.5	≈1.7	
Potassium	0.7	.42	0.35	
Chlorine	3x10^{-3}		2.4x10^{-3}	
Sulphur	7x10^{-2}	1.8x10^{-2}	0.24	
Phosphorus	5x10^{-3}	2.1	0.14	
Silicon		1.8	≈2.1	
Aluminum	.2	.12	≈0.48	
Magnesium	0.47	3.9	0.18	
Sodium	6x10^{-2}		0.11	
Fluorine	4x10^{-3}	.25	0.016	
Oxygen		NR	NR	
Nitrogen		NR	NR	
Carbon		NR	NR	
Boron	8x10^{-3}	9x10^{-3}	NR	
Beryllium	2x10^{-6}			
Lithium	3x10^{-4}		2.4x10^{-3}	

NOTE: NR--Not Reported
When no numbers appear, concentration is less than 1x10^{-5} ug/m^3

* Unable to determine because of blank level.

Table IV-22 VOLATILE TRACE METAL CONCENTRATIONS - $\mu g/m^3$ ON TRACT C-b

Date of Sample Collection	Selenium(1)	Mercury(2)	Arsine(3)
November 22, 1974	0.30	0.0350	8.00
January 27, 1975	0.00	0.0000	0.00
April 25, 1975	0.38	0.0055	9.74
July 25, 1975	0.16	0.0027	7.83

(1) Detection limit threshold 0.05 $\mu g/m^3$

(2) Detection limit threshold 0.001 $\mu g/m^3$

(3) Detection limit threshold 0.5 $\mu g/m^3$

Table IV-23 GROSS RADIOACTIVITY LEVELS ON TRACT C-b

PICOCURIES/m^3

Date of Sample Collection	Gross Alpha ± Precision (1)	Gross Beta ± Precision (1)
Composite of Samples, Nov. - Dec., 1974	$6.5 \times 10^{-4} \pm 2.7 \times 10^{-4}$	$11.4 \times 10^{-2} \pm 0.4 \times 10^{-2}$
Single Day Sample 12/4/74	$13.8 \times 10^{-4} \pm 8.2 \times 10^{-4}$ (3)	$13.2 \times 10^{-2} \pm 0.8 \times 10^{-2}$ (2)
Composite of Samples, Jan. - Mar., 1975	$6.3 \times 10^{-4} \pm 4.1 \times 10^{-4}$	$7.1 \times 10^{-2} \pm 0.1 \times 10^{-2}$
Single Day Sample 1/28/75	$3.4 \times 10^{-4} \pm 1.3 \times 10^{-4}$ (4)	$19.6 \times 10^{-2} \pm 4.2 \times 10^{-2}$ (2)

(1) Variability of radioactivity disintegration process (counting error) at the 95% confidence level.

(2) Blank Gross Beta 0.004 + 0.004 pc./cm^2 (420 cm^2/filter).

(3) Blank Gross Alpha 0.0004 + 0.0004 pc./cm^2 (420 cm^2/filter).

(4) Blank Gross Alpha 0.0007 + 0.0006 pc./cm^2 (420 cm^2/filter).

Table IV-24 SIZE DISTRIBUTION OF AIRBORNE PARTICULATE MATTER IN THE RESPIRABLE RANGES

Concentrations in g/m^3

Date of Sample \ Size Range in Microns*	7.0 - Above	3.3 - 7.0	2.0 - 3.3	1.1 - 2.0	0.01 - 1.1
January 27-28, 1975	1.77	1.89	6.62	2.13	5.44(1)
April 24-25, 1975	22.06	15.25	6.81	5.31	3.44
July 24-25, 1975	5.02	3.43	2.64	1.85	1.58
October 4-5, 1975	3.66	3.05	2.01	0.91	4.08(1)

* Aerodynamic diameter of the particulate matter.

(1) Two soot particles of much larger diameter were observed on filter, therefore, this is not an accurate ambient air concentration.

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V. BIOTIC COMMUNITIES

A. Introduction

1. Objectives

The primary objective of the biological studies of Tract C-b is to meet requirements of the Environmental Stipulations of the Oil Shale Lease. Section 1, Paragraph C(2d) of these Stipulations requires that the Lessee must study the fauna of the leased land and of lands lying within 1 mile of the leased lands over a two-year period. The purposes of these studies are to determine the species present, their spatial and temporal distribution and their relative abundance. Migratory patterns are also to be addressed. The terrestrial fauna studies satisfy the lease requirements by identifying species of major groups which occur within the study area on a seasonal and annual basis, by developing a designation of important species, by determining the density of principal species and by determining their use of dominant habitat types.

The Stipulations also require that studies be made of the flora and fauna of the aquatic environment of the leased land and at a distance downstream to be determined by the mining supervisor. These studies are required to address the same general topics as those being made of terrestrial flora and fauna. Springs and seeps are also to be inventoried. The aquatic studies satisfy these requirements by identifying species of major groups of flora and fauna at specified sampling points within the study area on a periodic basis, by determining the relative abundance of principal species and by identifying important interrelationships.

The Stipulations require that flora be studied on the leased land and on lands lying within 1 mile of the leased lands over a two-year period. The distributions, density and condition of the flora are to be determined. Plant-animal relationships are also to be addressed. The floral studies satisfy these requirements by identifying taxa of plants on Tract and the surrounding study area, by determining species characteristics in major plant communities and by relating plant community structure to functional aspects of both biotic and abiotic factors.

2. Quality Assurance and Data Accuracy

All Woodward-Clyde Consultants' project work is conducted in accordance with the company's Quality Assurance Manual, revised June 1, 1975.

A work plan and scope of work is prepared for the project. Data acquisition proceeds as outlined in the work plan. This involves literature search, field investigations and laboratory work. These are

conducted in accordance with standard or special methods and procedures as outlined in the work plan and detailed in procedural manuals.

Tools, samplers and instruments used in data collection in the field and laboratory are calibrated and adjusted periodically, as required, to assure data suitable for analysis. Calibrations are traceable to National Bureau of Standards or other recognized and approved standards.

Data analysis and interpretations are based on logical, systematic procedures. Where appropriate, statistical analyses of data are performed. Accurate records are kept so that the analysis process may be reconstructed by a knowledgeable reviewer. Only certified or crosschecked computer programs are used in analyses. Verification and crosscheck of field data are conducted prior to analysis by a qualified scientist and periodic checks are completed on all data through the reporting phase to maintain that quality.

3. General Description

The Tract is located in a transitional zone between the cold desert and mountain forest. The topography of rolling hills, interspersed with south-to-north stream valleys, is dominated by a pinyon-juniper, woodland complex. Vegetation in the valleys, where alluvial materials have accumulated, includes native plant communities principally composed of sagebrush, with some rabbitbrush and greasewood, and of cultivated areas occupied by introduced grasses.

Dendroclimatology studies (see Quarterly Data Report #3) indicate that the cyclic nature of the climate in the Piceance Creek Basin has a dominant average periodicity of eleven years. From 1959 to 1974 there has been an overall increase in winter precipitation.

Precipitation ranges from 12-24 inches per year and occurs primarily as spring and summer thunderstorms and winter snowfall. The annual growing season is approximately 90 days with the frost-free period ranging from 50 to 125 days per year. Relative humidity is low and many of the plants in the area have xerophytic properties such as heavily sclerotized leaves and root systems that reach to great depths.

Present productivity on the Tract is, in part, the result of past land-management practices. When Escalante passed through the area in the 1600's he found stands of tall grass, meadows and trees. Diagnostic work on the pinyon suggests that the pinyon-juniper complex was a climax forest in this area as early as 1437 A.D.; some of the pinyon trees located in the slopes of the Tract are over 500 years old. The area was overgrazed by sheep and cattle in the late 1800's and early 1900's. Approximately 45 percent of the Tract was chained in 1966 as part of the Bureau of Land Management's program to improve and maintain the natural grasslands and forage. Disturbance in the area has led to a community of grasses, shrubs and mixed introduced and native annual species.

Several rare and endangered species are listed as possibly being present in the Piceance Creek Basin but none of these species have been sighted on the Tract. Two subspecies of the endangered peregrine falcon (*Falco peregrinus* var. *anatum* and *Falco peregrinus* var. *tundrius*) occasionally occur in the area. The prairie falcon (*Falco mexicanus*) has been sighted near the Tract. The spotted bat, the black footed ferret, Colorado squawfish, humpback chub and pahranagat bonytail have all be designated by the Federal Government as endangered species, but none have been identified as occurring in or near the Tract. Colorado has designated the gray wolf, river otter and wolverine as endangered species. None have been sited on the Tract nor have they been identified in the Piceance Creek Basin.

B. Animal-Populations and Dynamics

1. Big Game

a. Methodology

The distribution, abundance, habitat use and movement patterns of mule deer, in and around the Tract, have been monitored by several techniques including track counts, road counts, aerial counts, winter mortality counts, pellet-group counts and shrub utilization surveys.

(i) Shrub Utilization

Deer pellet-group counts are used in determining the number of deer and their utilization of the major vegetation types. Sixteen, stratified, random transects for deer pellet-groups have been established to evaluate the importance of the mule-deer winter range. Each transect contains 50, 0.01 acre plots within which all pellet-groups are counted (Anderson, Medin and Bowden, 1972). Pellets deposited in each plot were scattered prior to the fall 1974 movement of deer into the area. New pellet-groups counted in May 1975 indicated the majority of deer had left the area.

Deer-days utilization/acre, number of deer/acre and total number of deer were calculated as follows (Overton, 1971):

$$\text{Deer-days utilization/acre} = \frac{\text{pellet groups/acre}}{\text{defecation rate}}$$

$$\text{Number of deer/acre} = \frac{\text{deer-days utilization/acre}}{\text{number of days in period}}$$

$$\text{Total number of deer} = \text{deer/acre} \times \text{number of acres}$$

The defecation rate of 13 pellet-groups per day is used (Smith, 1964; Rasmussen and Doman, 1943; Eberhardt and Van Etten, 1956). The number of days in a period, 216, was chosen between October 23 and May 12 by monthly road counts.

A shrub utilization study evaluates the extent to which deer utilize shrub species. Two methods are being used on Tract C-b. The first method rates browse species in each pellet-group plot with respect to relative cover and degree of browsing, the values for which are used to compute percent availability and percent utilization of each browse species.

Direct measurement of shrub material consumed by the deer is the second method. In this method browse species in every tenth pellet-group plot (150 meter intervals) were selected for tagging in the fall of 1974. Tags were placed at the location where the current year's growth had begun on four randomly selected shoots for each browse species. In the spring of 1975 measurement of the current year's growth remaining after winter browsing was used to calculate a percent utilization for each species. Species dry weight of clipped shoots will be used to estimate the biomass taken by wintering deer.

(ii) Bi-monthly Track Counts

The minimal sampling effort for the bi-monthly track counts consisted of identifying tracks in 10 quadrats (one transect) in each of four habitat types. Quadrats measured four meters on a side and were placed at 25 meter intervals. During the snow-free seasons, each quadrat was raked free of large debris, in the evenings fine dry soil was sifted over the quadrat when necessary and counts were made the following morning.

Data from track counts are expressed as a percent frequency which is calculated as the number of quadrats with tracks of a given species divided by the total number of quadrats. Quadrats are not included in the sample if 50% or more of the area has been disturbed by wind or cattle.

Apart from the information obtained concerning mule deer, data on cottontails and other less abundant species (coyote, bobcat, white-tailed jackrabbit) are routinely gathered by this method. Sampling intensity has been too low to statistically evaluate cottontail population trends, except after fresh snowfalls when the sampling effort can be increased. The occasional record of an uncommon species (badger, sage grouse) and the potential to detect rare species (black bear, mountain lion, ring tail) are considered valuable attributes of this method even though such data are not amenable to statistical analysis.

The most difficult sampling problem encountered with this method concerns placing quadrats such that there is an equal probability of track occurrence in each quadrat. Linear features of the landscape (old roads, dry creek beds) are convenient locations for quadrats, since they tend to have more suitable substrates and are more accessible. Many mammals will follow such linear openings, however, which will cause overestimates of abundance. This can largely be avoided by staggering quadrats to either side of these potential pathways.

(iii) Track Counts: Deer Migration Studies

A modification of the above method was used to estimate relative usage of major ridges traveled by mule deer during the fall migratory influx into the Tract C-b area. Study areas were selected within homogeneous stands of pinyon-juniper woodland on six major north-south ridges; five transect lines were established perpendicular to the long axis of each ridge. Transects were 90 meters long and positioned approximately 27 meters apart. Each transect consisted of 10 quadrats, one meter square, placed at ten meter intervals. Percent frequencies of track occurrences were calculated for the ten sampling days that occurred during September-October, 1975.

(iv) Track Counts on Fresh Snow

Following a fresh snowfall, little-used ranch roads often permitted track counts to be conducted by vehicle allowing a larger area to be sampled. Quadrat size was considered unimportant provided all quadrats sampled were of equal area. Areas of quadrats were visually estimated.

(v) Predator Scent-post Survey

This method, developed by the U. S. Fish and Wildlife Service, is presently being implemented in 17 western states. The scent-post survey is a track-count method which employs an attractant to draw coyotes (and other predators) to a prepared station. A station consists of a 3-foot circle of sifted earth with an attractant placed in the center. Fifty stations are located at 3/10 mile intervals covering a distance of 15 miles. Each 50-station line is checked for three-to-five successive days. A relative index of abundance is calculated as a visit frequency.

(vi) Deer Road Counts

Road counts were conducted during late evening by traveling 36 miles along county highway 5 from Little Hills Game Experiment Station to Rio Blanco and in the reverse direction. Deer occurrences per habitat type were recorded at one-mile intervals. Tallies of deer, information on weather and other observations were recorded.

(vii) Air Reconnaissance for Deer Distributions away from Roads

Air reconnaissance during winter was conducted at monthly intervals following fresh snowfalls. Eight transects were flown perpendicular to the drainages of Piceance Creek at about 50 feet above ground level using fixed-wing aircraft. The area of coverage included Tract C-b plus approximately five miles of the surrounding area. Based on aerial observations of tracks on snow, the abundance of deer tracks were ranked as none, low, medium, high or very high for ridge tops, slopes and valleys.

(viii) Deer Mortality Studies

Carcasses of deer that had died on Tract C-b and study area were examined in five habitat types during May and June 1975. Quadrats were randomly positioned in four habitat types using aerial photographs to pinpoint locations and quadrats were subjectively located in the lateral draw habitat. Sizes of quadrats were generally four hectares. In the small lateral draws quadrats averaged 0.21 hectares. Data were gathered only when at least the skull or pelvic girdle or one mandible was present. Criteria used to estimate the year of death were: 1974-75 deaths, a yellow-brown bone color, considerable connective tissue with an oily feel, scattered hair having a fresh appearance; 1973-74 deaths, bones bleached white with the remaining connective tissue dry (not oily); 1972 and earlier deaths, weathered bones (cracks, flaking). Judgments of rates of carcass decomposition were facilitated by marking and photographing carcasses the previous fall. The age of the deer at time of death was estimated by tooth-wear criteria (Giles 1969).

(ix) Mammalian Identifications

Identifications of desert cottontails and other species difficult to identify were made using the criteria of Armstrong (1972), Lechleitner (1969) and White (1953).

b. Major Findings of the First Year of Baseline Studies

(i) Results of Pellet-Group Survey

The pellet-group survey results (Table V-1) were evaluated 1) by association of pellet-group totals with major vegetation type and 2) pellet-groups were totaled for higher elevations above the Tract, elevations through the Tract and south-facing and exposed lower slopes north of the Tract.

From data in Table V-1 it is apparent that the upland sagebrush and chained pinyon-juniper rangeland are important browse areas during the winter. Deer-days utilization per acre was 37.2 and 28.4, respectively, for these two habitat types. High utilization may be attributed to increased cover of and accessibility of preferred browse species in the chained pinyon-juniper and the accessibility of the plateau sagebrush when other feeding areas have more snow accumulation.

When pellet-group numbers and deer utilization by elevation were compared, deer-days/acre was highest at the 7100' elevation followed by 26.7 deer-days/acre for the entire Tract. The lowest value of 19.4 deer-days/acre was calculated for the lower exposed slopes north of the Tract. Although observation suggests heavy utilization of these lower south-facing slopes in late winter and early spring, such utilization may occur for a relatively short period of time. Browse species along these transects are not very abundant and are heavily hedged.

Table V-1 RESULTS OF PELLET GROUP SURVEYS IN AND AROUND TRACT C-b DURING WINTER 1974-1975.

	Vegetation Type				Elevation			
	Pinyon-Juniper	Chained P-J	Upland Sagebrush	Valley Sagebrush	Tract C-b Study Area	C-b Boundary	Piceance Creek	7100 Elevation
Number pellet groups	1413	532	512	93	2550	1389	758	403
Number of plots	509	144	106	41	800	400	300	100
Total number acres sampled	5.1	1.4	1.1	.41	8	4	3	1
Pellet groups/acre	277.6	369.4	483.0	226.8	345.8	347.2	252.6	403
Mean pellet groups	74.4	76.0	102.4	23.2	72.8	173	126	202
Confidence Interval on Mean	±27.6	±68.7	±75.6	±15.3	±20.5	±56.3	±36.9	±88.4
Deer-days utilization/acre	21.4	28.4	37.2	17.4	26.6	26.7	19.4	31
Number of Deer/acre	0.09	0.13	0.17	0.08	0.12	0.12	0.09	0.14
Number of Deer/hectare	0.24	0.33	0.42	0.20	0.30	0.31	0.22	0.36

Fourteen plant species were rated for percent availability and percent utilization to determine their relative importance for forage (Table V-2). Three of these species, big sagebrush, bitterbrush and rabbitbrush provided the majority of winter diet for mule deer in the Tract C-b study area. Big sagebrush provides the greatest amount of vegetation cover, i.e., the percent available to deer for browsing in all areas. Rabbitbrush is second-most available species in all areas except pinyon-juniper and chained pinyon-juniper areas where snowberry is second-most available browse species.

Percent utilization, a measure of the relative use of the shrubs by deer, is computed by multiplying relative cover values by degree of browsing values. For example, in the valley sagebrush,although 80% of the vegetation cover is represented by big sagebrush, only 24% of the available sagebrush is utilized (80% cover x 30 ((= moderate browsing)) =24%). Rabbitbrush, on the other hand, makes up approximately 15% of the shrub cover and is heavily utilized (72.4% utilization). Shrub species which are utilized in percentages above their availability are generally heavily hedged and in poor-to-fair condition.

Based on relative cover and utilization, big sagebrush is the most important browse species. Antelope bitterbrush, serviceberry and mountain mahogany are also important browse species and were moderately to severely hedged in all transects implying their utilization is greater than their availability.

Although pinyon pine was not rated for percent availability or percent utilization within the browse survey transects, qualitative observations suggest that pinyon needles from lower branches are utilized in significant quantities during the late winter season when preferred browse species are in poor condition. Recent studies in Piceance Creek Basin support this observation (Hansen and Dearden, 1975). Juniper did not appear to be utilized in any significant quantity.

Values obtained for utilization of tagged shoots by mule deer on Tract C-b (Table V-3) confirm that big sagebrush is the most important browse species as indicated by ratings of cover and utilization. The low 53.5 utilization of big sagebrush within the valley-sagebrush vegetation-type indicates that although sagebrush is available for consumption it is only moderately utilized.

(ii) Mule Deer Movement Patterns

Deer movement patterns have been separated into two categories, local movements--the seasonal changes in habitat usage and the areas of local concentrations--and migrational movements--the routes taken by the deer during their fall migratory influx.

<u>Local Movements of Mule Deer</u>

Seven, major, habitat types have been defined for Tract C-b along with a number of subunits. The habitat units defined are applicable to deer as well as other terrestrial vertebrate species.

Table V-2 WINTER DEER BROWSE EVALUATION AND UTILIZATION

Browse Species	Tract C-b Study Area % Available	% of Diet	Pinyon-Juniper % Available	% of Diet	Chained Pinyon-Juniper % Available	% of Diet	Upland Sagebrush % Available	% of Diet	Bottomland Sagebrush % Available	% of Diet
Mountain Mahogany	5.7	9.8	9.9	13.7	5.1	10.7	.6	.9		
Antelope Bitterbrush	7.2	11.9	11.5	20.3	9.8	21.3	.4	.5		
Big Sagebrush	50.6	45.3	36.2	30.4	54.0	48.7	68.1	77.0	80.3	23.9
Serviceberry	6.7	10.7	11.0	14.7	2.4	2.3	.8	.4		
Snowberry	10.0	3.0	12.6	5.1	17.0	5.4	3.3	.3	2.4	.6
Gambel's Oak	1.9	2.5	2.8	3.0	.2	.4	.6	.9		
Rabbitbrush	14.4	15.1	11.6	10.6	11.5	11.2	21.5	19.0	15.6	72.4
Greasewood	.5	.5	1.0	1.1						
Saltbush	.5	.1	.9	.1						
Winterfat	1.4	.5	1.0	.5			4.2	.6	1.5	2.6
Juniper	Trace	.1	.1	.1						
Pinyon Pine	.5	.1	.7	.1						
Wild Rose	.1	Trace	.1	Trace						
Skunkbush	.5	.4	.6	.3			.4	.4	.2	.5
Deer Days Utilization/ Acre	26.6		26.6		28.4		37.2		17.4	
Number of Deer/Acre	.123		.099		.132		.172		.081	

Total Number of Deer: 625

NOTE: (% Available = % Cover; % of Diet = % Species Utilization from Browse Ratings)

Table V-3 MULE DEER SHRUB UTILIZATION VALUES DETERMINED FROM TAGGED SHRUBS. DATA SUMMARIZED BY MAJOR HABITAT TYPES OVER TRACT C-b

	Pinyon-Juniper			Chained Pinyon-Juniper			Plateau Sagebrush			Valley Sagebrush		
	Artr[1]	Amal[1]	Cemo[1]	Artr	Amal	Cemo	Artr	Amal	Cemo	Artr	Amal	Cemo
Number sampled	92	44	52	40	-	8	40	4	4	16	-	-
Mean current year's (1974) growth ($\bar{x}_1$) in cm	4.3	5.2	7.9	6.5	-	10.0	3.4	4.9	2.9	5.2	-	-
C.I.[2] on $\bar{x}_1$	$\bar{x}_1 \pm 0.7$	$\bar{x}_1 \pm 1.5$	$\bar{x}_1 \pm 1.6$	$\bar{x}_1 \pm 1.4$	-	$\bar{x}_1 \pm 4.9$	$\bar{x}_1 \pm 0.6$	$\bar{x}_1 \pm 1.7$	$\bar{x}_1 \pm 1.1$	$\bar{x}_1 \pm 2.2$	-	-
Number sampled	92	44	52	40	-	8	40	4	4	16	-	-
Mean growth remaining after winter browsing ($\bar{x}_2$) in cm	0.7	2.0	1.1	1.4	-	2.8	0.5	1.1	0	2.4	-	-
C.I.[2] on $\bar{x}_2$	$\bar{x}_2 \pm 0.4$	$\bar{x}_2 \pm .6$	$\bar{x}_2 \pm 0.6$	$\bar{x}_2 \pm 0.6$	-	$\bar{x}_2 \pm 2.0$	$\bar{x}_2 \pm 0.1$	$\bar{x}_2 \pm 3.6$	0	$\bar{x}_2 \pm 1.8$	-	-
Per cent utilization (calculated from means)	83.6	61.7	85.6	79.2	-	72.0	86.0	76.0	100.0	53.5	-	-

1. Artr = *Artemisia tridentata*
   Amal = *Amelanchier alnifolia*
   Cemo = *Cercocarpus montanus*

2. 95% confidence interval of the mean.

The pattern of occurrence in those habitat types, which are of significance to deer either as feeding or bedding areas, is shown in Figure V-1. The patterns (Figure V-1) are influenced in large part by seasonal changes and changing availabilities of preferred browse plants. Curves represent qualitative estimates of deer densities in one habitat type relative to another over a one-month time period. The proportion of the local deer herd using a given habitat type is dependent on habitat area as well as the total number of deer.

Pinyon-juniper woodland, chained pinyon-juniper rangeland and upland sagebrush comprise the vast majority of the surface area on Tract C-b. Each of these habitat types is a significant component of deer winter range. As previously mentioned, deer are virtually absent from Tract C-b during summer. While vegetational differences between habitats are pronounced, all three contain major browse species.

As determined by local counts, certain agricultrual meadows in the vicinity of Tract C-b are heavily used by deer during the early fall and again during spring. These meadows do not occur within the Tract boundaries (Figure V-2). The length of road traveled while conducting these counts extended approximately 15 miles to either side of Tract C-b and, consequently, the data help place Tract C-b within a broader, environmental context. During October and November of both 1974 and 1975, large concentrations of deer were observed in meadows at the mouth of Sorghum Gulch; during spring, when meadow concentrations again occurred, concentrations tended to be shifted downstream several miles, centering on the area north of the Tract's western boundary. The reasons why deer used certain meadows more heavily than others are not known. However, it is clear that the presence of alfalfa in the fall and the early growth of grasses in the spring attracted the deer. These factors resulted in impressive numbers of deer occurring in localized areas. The highest deer concentration observed occurred during May 1975 when 208 deer were counted within one-mile of the confluence of Willow Creek with Piceance Creek.

The degree to which the meadow concentrations relate to deer distributions in other areas is considered an important but largely unanswered question. At the present time the road count suggests that C-b Tract area supports higher concentrations of deer than other areas within a 15-mile radius (Figure V-2). This may be misleading and may only partially reflect deer densities in dissimilar but nearby habitat types.

Lateral draws were singled out as special habitat features. These features occur as small, steep-sided draws along the lower sections of the major, north-south, valley systems in the Tract C-b area. Lateral draws are typically composed of mixed-mountain shrub on north-facing slopes, bunchgrass and frequently rimrock on south-facing slopes and big sagebrush covering small alluvial fans. Their importance to deer seems to be the protection provided during brief but severe winter storms. The south-facing slopes, which typically remain snowfree, are heavily used during times of widespread, deep and crusted snow. The shrubs on the adjacent north-facing slopes are utilized by the deer to the extent

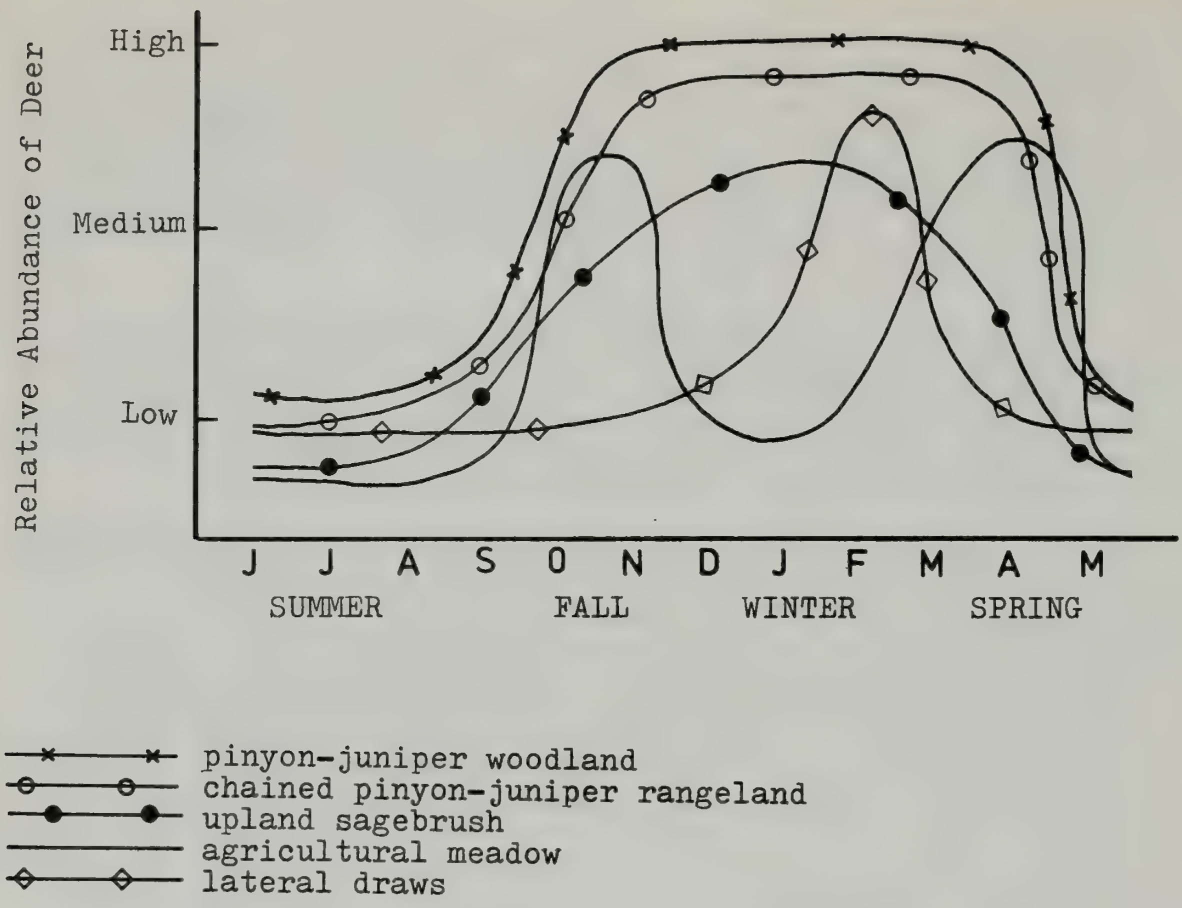


Figure V-1 Mule deer occurrence in five habitat types for a 12-month period, 1974-75. The study area includes Tract C-b plus the one-mile surrounding zone. Distributions are on field observations, track counts, and winter aerial reconnaissance.

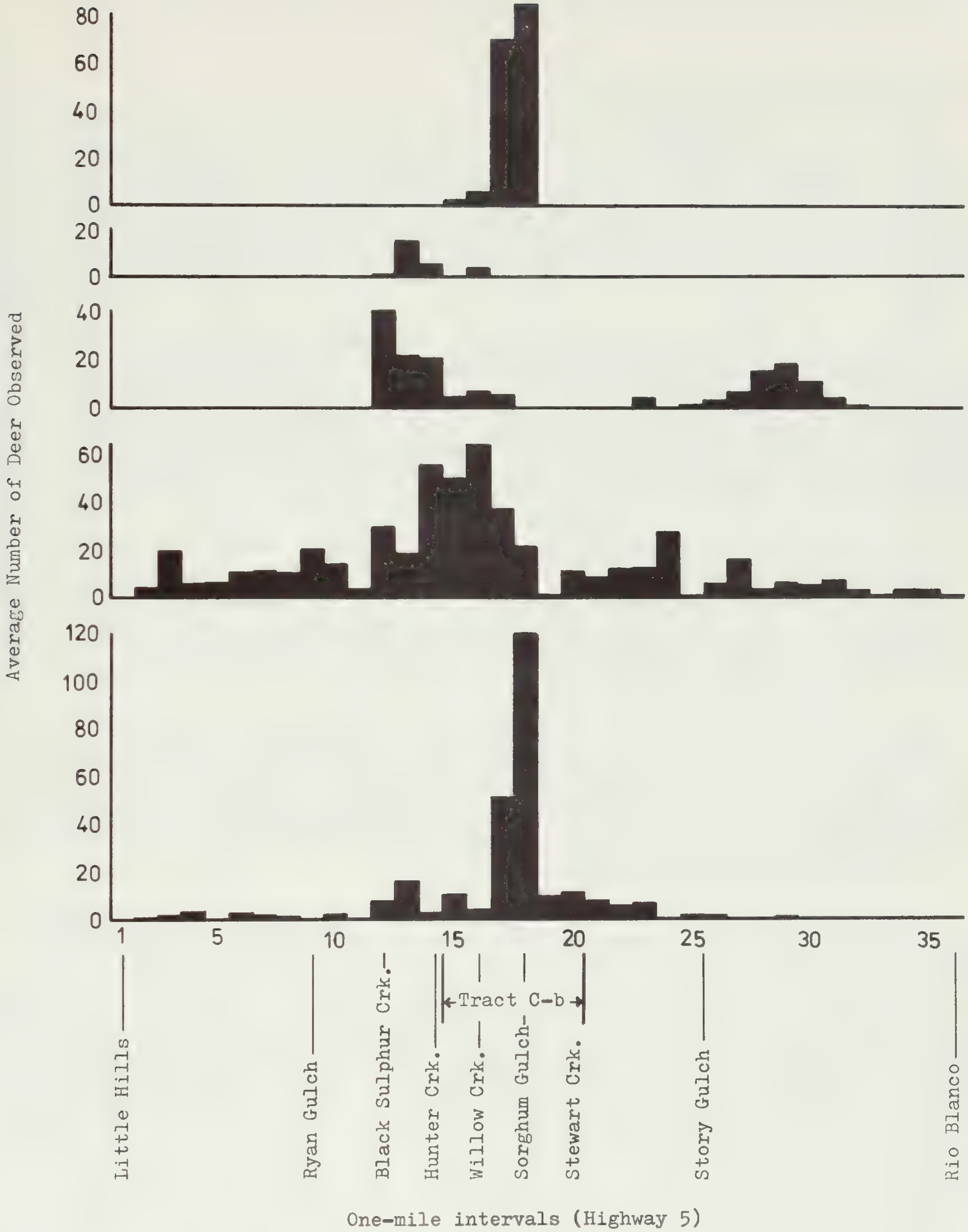


Figure V-2 Summary of deer road counts, 1974-75. Means for each mile interval are based on the following number of evening road counts: 5 for Oct-Nov 1974; 3 for Dec-Jan 1974-75; 2 for Feb-March 1975; 5 for April-May 1975; and 5 for Oct-Nov 1975.

snow-pack conditions allow. Deer mortality studies have shown that most of the winter deer mortalities in the Tract C-b area occur within these lateral draws.

Migrational Movements of Mule Deer

The migrational movements of deer were studied only as they relate to the immediate vicinity of Tract C-b. No studies were performed to establish how far the local,wintering deer herd travels during summer. The duration of time that deer remained in the vicinity of Tract C-b during 1974-75 was eight and one-half months from October to mid-May. Deer were virtually absent from the Tract area during the remaining time.

During the fall of 1975 track-counts were made on six major north-south ridges to estimate the relative importance of the main ridges as travel routes and to measure more carefully the duration and timing of the migratory influx. The ridges most heavily used were between Willow Creek and Scandard Gulch, between Sorghum Gulch and the West Fork of Stewart Creek (Figure V-3). However, the results do not indicate that any of the six ridges are critical migrational pathways.

The duration of the fall influx was greater than seven days. Three hundred quadrats were checked on 9 October, only one contained deer tracks; similar low frequencies had been observed during the previous 10-day period. On 16 October, 94 quadrats contained deer tracks, and this higher frequency was maintained over the following 6 days, at which time the study was concluded.

The short period of time over which the influx occurs is very apparent in the field and at the outset deer can be seen in many habitat types where they seemed entirely absent only the week before. The chained pinyon-juniper and upland-sagebrush habitat types seem little used at these times, although it is likely that deer commonly frequent these open areas during the night.

The boundaries of winter and summer ranges are dynamic zones, varying seasonally and to some extent from year to year. On three centrally-located ridges south of Tract C-b browse and pellet-group studies indicated that summer and winter ranges overlap between 7500 and 7800 feet (Keammerer and Stoecker, 1975). During mild, winter weather deer have commonly been found at these higher elevations in mixed mountain shrub and upland sagebrush at approximately the upper limits of pinyon-juniper woodland. Similarly, during summer deer are occasionally seen at these same elevations. It appears, however, that the heaviest use of this overlap zone occurs during fall and spring, with limited use occurring during the hottest and coldest seasons. This observation was substantiated by track counts conducted during November following a light and uniform snowcover. Quantitative track counts made over two ridges leading south from Tract C-b (elevation 6900 feet) to the Piceance Creek/Parachute Creek divide (elevation 8500 feet) showed the highest deer numbers to be in the 7500-7800 foot zone (Figure V-4).

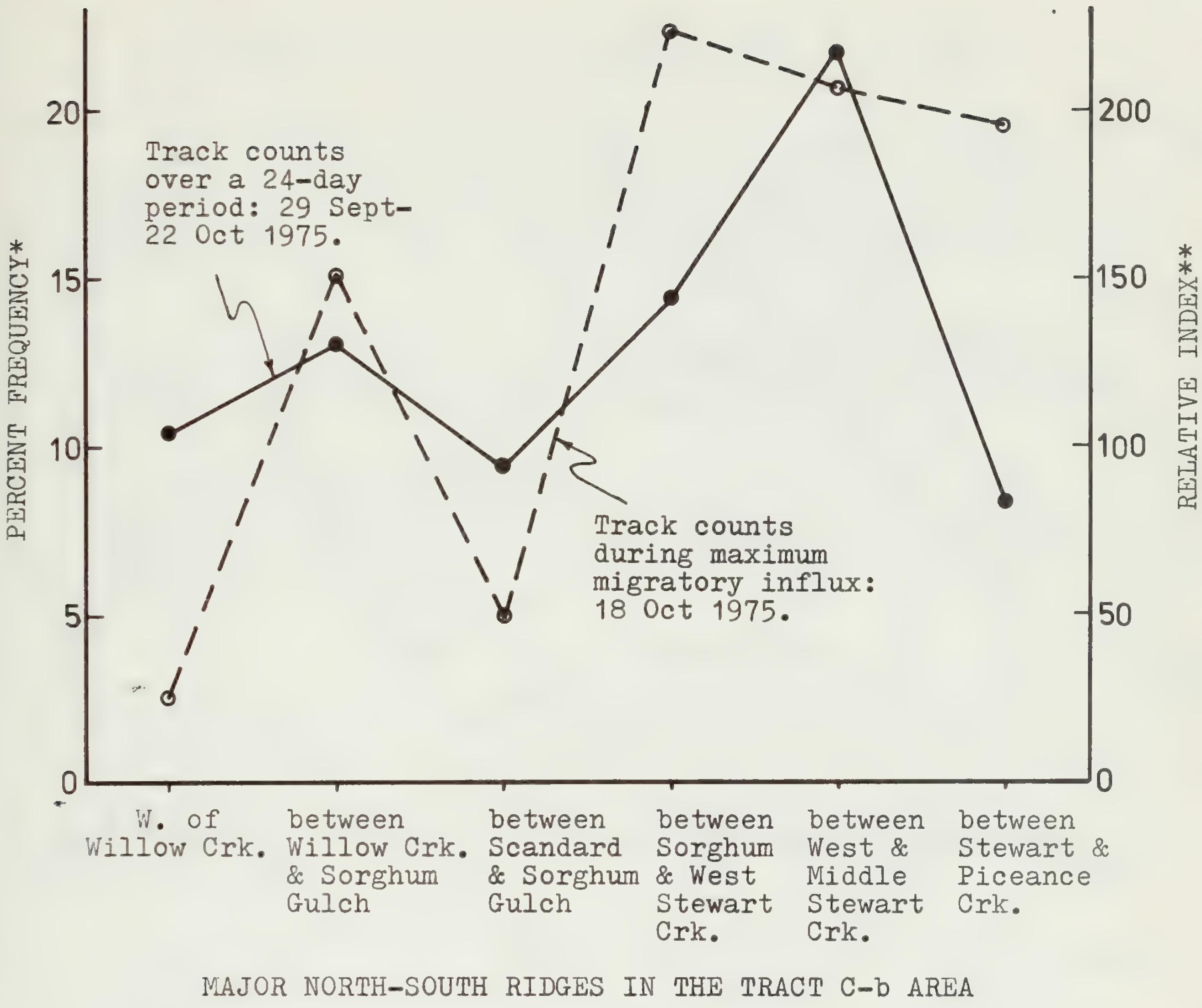


Figure V-3 Deer migration routes into the Tract C-b area during the fall of 1975. All sampling sites were located on ridges within pinyon-juniper woodland.

* Percent frequency (solid line) = number of quadrats with tracks/total number of quadrats x 100.

** Relative index (dashed line) = number of tracks observed which crossed a one-km continuous transect.

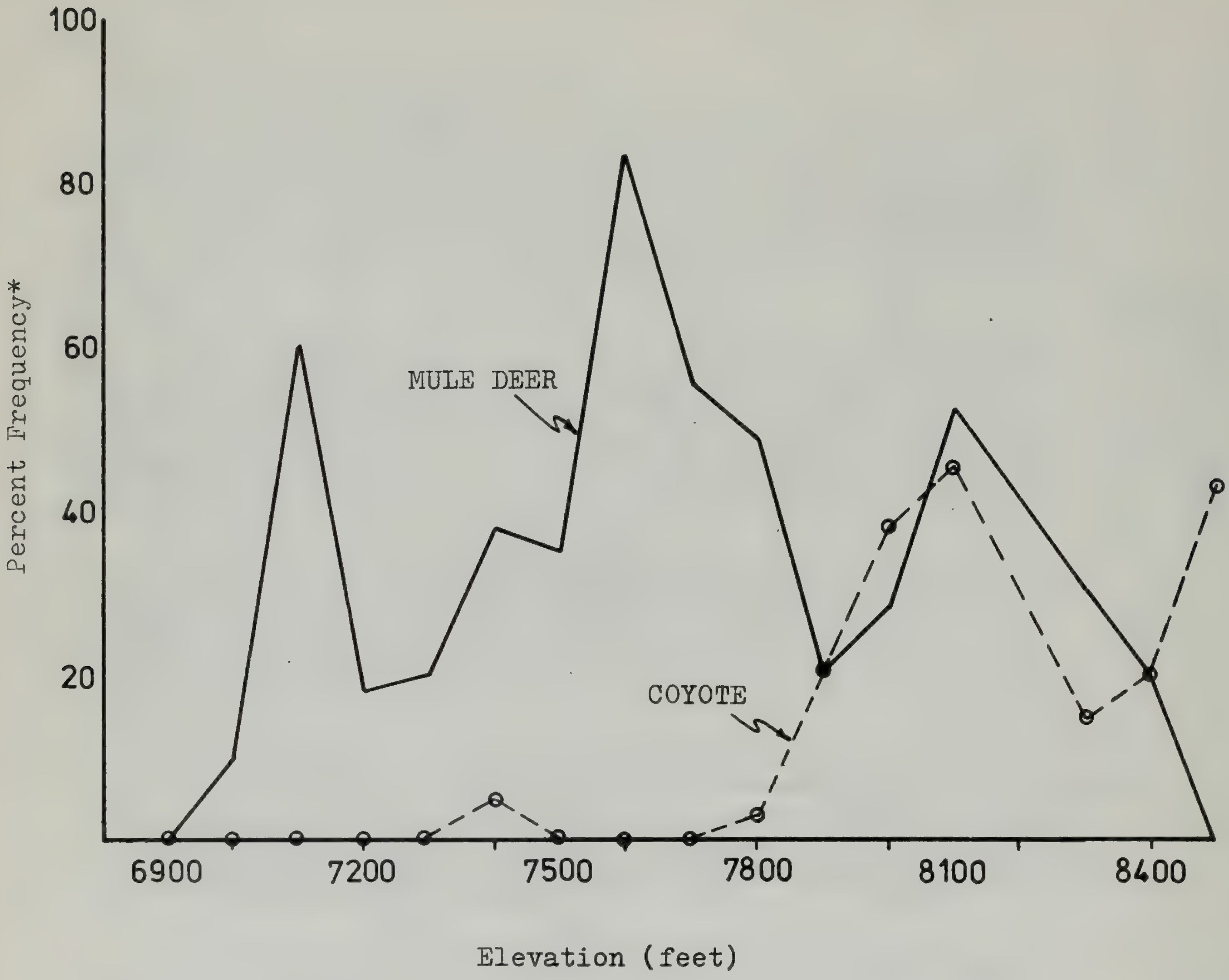


Figure V-4 Abundance of mule deer and coyotes along an elevational gradient from Tract C-b to the Piceance Creek/Parachute Creek divide. Counts were conducted 20 November 1975 on a nearly uniform 4-inch snowcover. Data are combined for two major north-south ridges (between Scandard Gulch and West Stewart Creek, and between West Stewart and Middle Stewart Creek).

* Percent frequency = number of quadrats with tracks/total number of quadrats x 100.

(iii) Mule Deer Mortality

The main concern of the deer mortality study was to determine the locations where deaths occur and to consider these data in terms of their significance as indicators of habitat importance.

This study provided information on total deer mortalities for the previous five years approximately. Results indicated that the vast majority of winter kill occurs in the more sheltered lateral draws and in topographically similar, valley sagebrush areas near the agricultural meadows (Table V-4). These areas are important to deer during brief periods in winter when the draws provide forage and shelter.

An estimated 450 deer (15/square mile) died in the 1974-75 winter on Tract C-b and within a one-mile surrounding area. Hunter harvest and road kills contributed perhaps an additional 100 deaths for a total 550 deer mortalities (19/square mile) for a 28.36 square mile area.

Age-class data obtained during the past year contribute to the assessment of the status of the local deer population. In particular, fawn-doe ratios (Table V-5) are useful in evaluating both reproductive success and fawn mortality over winter periods. Such information will be of value in recognizing future trends.

(iv) Livestock-Deer Relationships

Tract C-b is grazed by cattle during portions of the year, under the jurisdiction of the Bureau of Land Management; thus some degree of competition between deer and cattle on the Tract may exist. To determine the amount of competition between deer and cattle it is necessary to know their distribution and abundance, the period of time which each utilizes the Tract and the area and number of forage species browsed or grazed in common.

Deer pellet-groups established that approximately 600 deer were present on Tract C-b during 1974-75. Deer occupy the Tract and surrounding area from approximately October through May, depending on climatic conditions. Observations from August 1974 through September 1975, indicate that, after wintering away from Piceance Creek, cattle are released to graze in the hay meadows in early spring. As the growing season progresses, the cattle move away from the hay meadows, pass through Tract C-b and summer at higher elevations south of the Tract. As winter approaches the cattle move down from the summer range, pass through Tract C-b and utilize the hay meadows extensively. During this period, as in the spring, cattle passing through graze on the Tract. After November 1974 and October 1975, few, if any, cattle were utilizing the Tract. Productivity measurements for the herbaceous layer in 1975 support this observation (Table V-6). Also,studies have shown that where dual use of summer-early-fall range by cattle and deer occurs, cattle consume grass and grasslike plants in abundance while grasses are insignificant in the diet of mule deer (Lovaas 1958; Wilkins 1957; Dusek 1975). In these areas of dual usage forbs were the most important item in the mule-deer diet (Reynolds 1960).

Table V-4 DISTRIBUTION OF DEER CARCASSES[1] IN FIVE HABITAT TYPES

Habitat Type	Number of Carcasses Found (No./Acre)	Number of Carcasses Expected If Randomly Distributed	Number of Acres Sampled In Each Habitat[2]
Pinyon-juniper woodland	22 (0.3)	46	79
Chained pinyon-juniper rangeland	7 (0.1)	46	79
Valley sagebrush (6500 ft.)	17 (0.4)	23	40
Lower agricultural meadows and adjacent valley sagebrush	77 (1.0)	46	79
Lateral draws	48 (2.7)	10	18

1 Carcasses are not randomly distributed ($X^2 = 204$; df = 4; $P < .001$).

2 Total area sampled = 119.25 hectares (295 acres).

Table V-5 AGE-CLASS COMPOSITION OF MULE DEER WINTERING NEAR TRACT C-b

Date	Fawns	Does	Fawns/100 Does
19 November 1974	89	67	133
24 March 1975	141	154	96
19 April 1975	82	103	80
3 May 1975	85	113	75
21 November 1975	36	32	113

Table V-6 MEAN HERB PRODUCTIVITY FOR PERMANENT PLOTS 1 THROUGH 6* FOR TRACT C-b, 1975

	May	June	July	August
Stand 1, Chained Pinyon-Juniper Rangeland (Experimental Site)				
lbs/A	124 ± 22	314 ± 43	542 ± 162	255 ± 72
(Kg/HA)	(139 ± 25)	(352 ± 48)	(607 ± 181)	(286 ± 81)
Stand 2, Chained Pinyon-Juniper Rangeland (Control Site)				
lbs/A	127 ± 26	282 ± 40	376 ± 120	228 ± 52
(Kg/HA)	(142 ± 29)	(316 ± 45)	(421 ± 135)	(255 ± 58)
Stand 3, Upland Sagebrush Community				
lbs/A	268 ± 18	464 ± 45	499 ± 37	346 ± 39
(Kg/HA)	(300 ± 20)	(520 ± 50)	(599 ± 42)	(388 ± 44)
Stand 4, Bottomland Sagebrush Community				
lbs/A	72 ± 14	278 ± 33	227 ± 61	120 ± 24
(Kg/HA)	(79 ± 16)	(312 ± 37)	(254 ± 68)	(135 ± 27)
Stand 5, Pinyon-Juniper Woodland (Experimental Site)				
lbs/A	64 ± 16	171 ± 37	207 ± 80	128 ± 46
(Kg/HA)	(72 ± 18)	(192 ± 42)	(232 ± 90)	(143 ± 51)
Stand 6, Pinyon-Juniper Woodland (Control Site)				
lbs/A	107 ± 19	220 ± 41	209 ± 35	270 ± 50
(Kg/HA	(120 ± 21)	(246 ± 46)	(234 ± 39)	(303 ± 56)

*Plus and minus values are equal to standard error of the mean.

It appears that the present pattern of use precludes large numbers of deer and cattle from occupying Tract C-b simultaneously. However, dual usage of vegetation types does occur for a limited period during April, May and October when both species utilize hay meadows in Piceance and Willow Creek valleys outside the Tract C-b boundary but within the Tract C-b study area.

2. Other Large Mammals in the Vicinity of Tract C-b

Elk occasionally occur within the boundaries of Tract C-b as evidenced by tracks and fecal pellets. An unknown number of elk are reported to have spent at least part of the winter (February 1975) within the one-mile surrounding zone. Elk were sometimes observed at higher elevations to the south of the Tract.

There have been no sightings or evidence of black bear, mountain lion or feral horses within the Tract C-b study area.

3. Medium-sized Mammals

Medium-sized mammals identified within the study areas include the desert cottontail, coyotes, bobcat, badger, raccoon, striped skunk, porcupine, white-tail jackrabbit, muskrat and beaver.

Desert cottontails, ecologically important because they are a major prey species, were only common in certain localities during this past year. Marked yearly changes in densities may occur in the Tract areas as claimed by some local residents. Such fluctuations have the potential of influencing the population of bobcats and some raptorial birds.

Estimates of the abundance of cottontails were made at bi-monthly intervals in four,major habitat types (Figure V-5). Occurring in all four habitat types, they are most abundant in the valley sagebrush. Because the valley sagebrush is often found in close association with rimrock, these two habitat types are of special significance to bobcats and several species of raptors, notably the red-tailed hawk, golden eagle and great horned owl (see section on Avifauna). The rimrock areas are important to these predatory species as den sites, nesting areas and hunting areas.

Coyotes are common in the Tract area and occur in most habitat types. Results of standard, scent-post surveys and field observations indicate that the abundance of coyotes in the Tract vicinity is high compared to other areas in Colorado. During September, 1974 the scent-post count on Tract (188) ranked third highest in the state and highest in the mountainous region of the state (U.S.D.I. 1974). Indices are not available at this time for 1975.

Coyote tracks were recorded during the majority of bi-monthly track counts conducted in Tract C-b (Figure V-5). Based on field observations, West Stewart Creek, between the 6600 and 6800 foot elevations and the

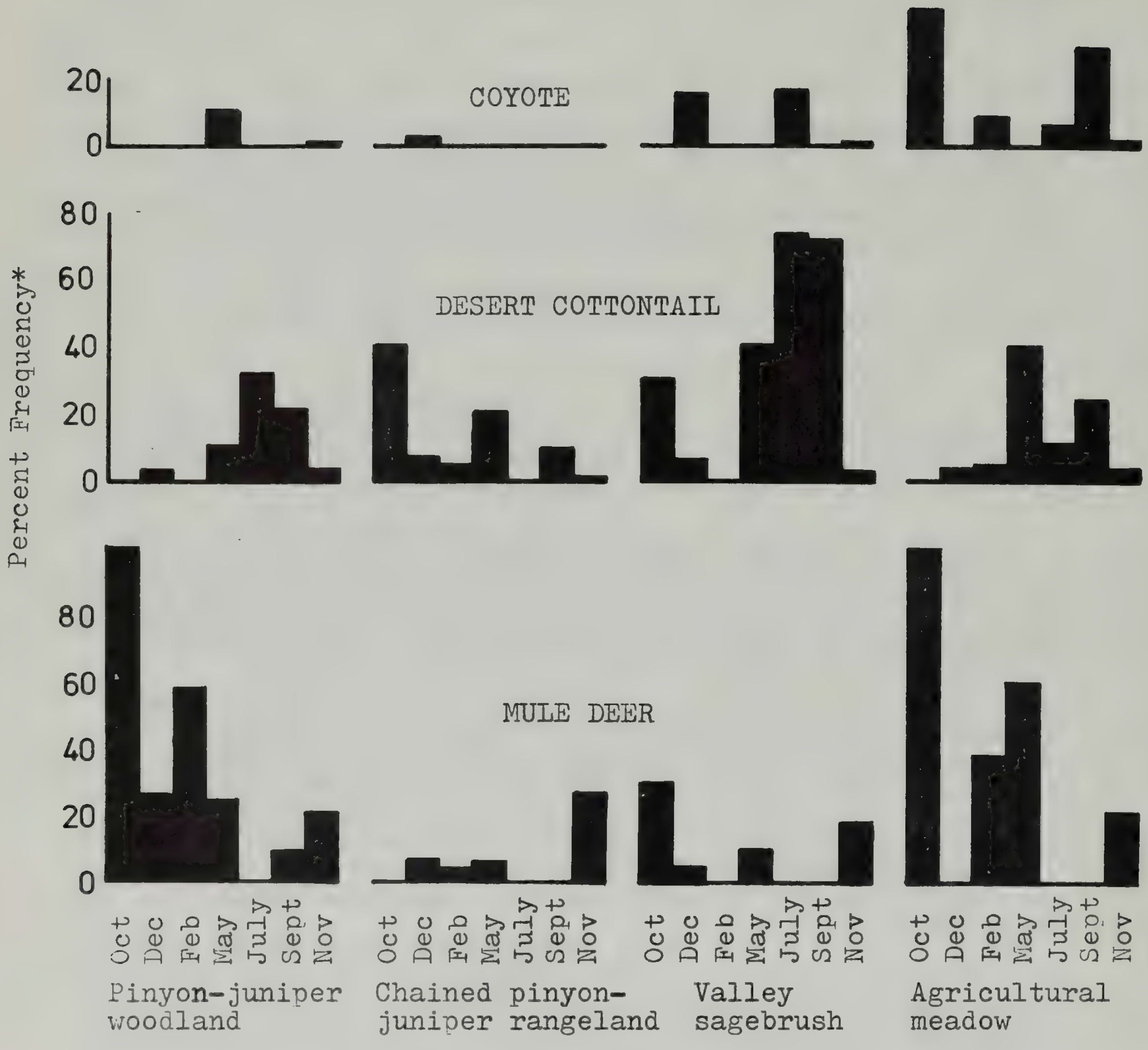


Figure V-5 Summary of bi-monthly track counts for 1974-75. Seasonal variation in abundance in four habitat types is presented for three common mammals.

* Percent frequency = number of quadrats with tracks/total number of quadrats x 100.

agricultural meadows near Cottonwood Gulch and Sorghum Gulch were important to coyotes during the late summer, fall and early winter of 1974 when high populations of the montane vole, an important prey species, were found in these particular meadows.

Additional quantitative data on coyotes were obtained during the deer track survey in November 1975 (Figure V-4). At this time coyotes were most abundant at the higher elevations, a distributional pattern believed to exist during summer also. Field observations and aerial reconnaissance indicate that the highest coyote density shifts to lower elevations during mid-winter and early spring when deer carrion from winter-kills provides an abundant food source.

Bobcats are most common the rimrock areas on Tract C-b, although signs of bobcat activity are occasionally seen in other habitats as well.

Badgers are uncommon on Tract C-b. While no direct sightings have been made, recent diggings were observed in the lower section of Sorghum Gulch in the existing Richardson's ground squirrel colony. Badgers have been observed on several occasions within five miles of the Tract boundary.

Raccoons are common along Piceance Creek and tracks were once observed on top of a nearby ridge in pinyon-juniper woodland.

Striped skunks are uncommon in the Tract area although they have been observed in the lower valleys along streams and in the upland, chained and pinyon-juniper habitats. Judging by the number of skunks observed killed along county highway 5, it appears this species is far less common here than along the Colorado River south of Tract C-b.

Porcupines are common at the higher elevations to the south of Tract C-b and most frequently have been observed in the mixed mountain shrub near aspen groves. On Tract C-b porcupines are less common although they have been observed in the pinyon-juniper and mixed-mountain-shrub habitat types.

White-tailed jackrabbits are uncommon on Tract C-b although they have been observed in a variety of habitat types. In the vicinity of Tract C-b populations appear to be highest near the Piceance Creek/Parachute Creek divide. However, even at these higher elevations they are not abundant.

Muskrats are common in Piceance Creek and in the nearby ponds and irrigation ditches. They tend to be most numerous in areas with appreciable riparian vegetation.

Beavers are rare near Tract C-b. No signs of past activity in the study area have been identified although one sighting of a beaver in Piceance Creek within the study area has been reported.

Mammals of the medium-sized category not yet identified but which could possibly occur within the Tract boundaries include the mountain cottontail, black-tailed jackrabbit, yellow-bellied marmot, gray fox, red fox, kit fox and ringtail. No national or state endangered mammal is believed to occur on Tract C-b or within the one-mile surrounding zone. The following species of presently endangered mammals could possibly have occurred in the area during pre-settlement days: black-footed ferret (nationally endangered), gray wolf, river otter, and wolverine (all endangered in Colorado). The habitat conditions of the pre-settlement environment, however, was probably not well suited to any of these species.

4. Small Mammals

a. Methodology

Small mammals on the Tract are represented by shrews, ground squirrels, chipmunks, gophers, wood rats, mice and voles. They are relatively abundant throughout the Tract and are being studied both quantitatively and qualitatively by the use of live and snap traps. Because approximately 83 percent of the Tract is represented by pinyon-juniper woodland and chained pinyon-juniper rangeland, quantitative grids were established at two locations to represent both major habitat types.

At each study plot 152 Smith live-traps were placed as shown in Figure V-6. Traps are baited with rolled oats,and during colder months corn is mixed with oats to serve as a high-energy supplement. In addition to the use of corn, a wad of cotton batting is placed at the back of each trap for bedding material to minimize the numbers of deaths from hypothermia.

Trapped animals are marked by two different methods. Animals too small to be ear-tagged (deermice, voles, pocket mice, chipmunks) are toe-clipped while larger animals (rabbits, squirrels, wood rats) are ear-tagged with monel tags. In addition to tagging animals the sex, life-history stage, weight, reproductive state and presence of parasites are recorded for each capture. Live body-weights of animals are recorded with a Pesola spring scale read to the nearest 0.5 gm. Biomass values are calculated from the mean, live body-weights. The information is transferred to computer punch cards and analyzed on an IBM 360/67 computer.

To assess the distribution of small mammal species on Tract C-b and determine their specific habitat preferences, an array of nine satellite grids was established. A satellite grid is a 4 x 6 array of Smith live-traps placed 15 meters apart. Animals caught in these grids are not permanently marked. All trapping sites are shown on Figure V-7. The nomenclature used for small mammals follows that of (Lechleitner, 1969).

Museum-Special traps using rolled oats as bait were placed in 25-trap, transect lines to collect rodents. Transects were located at sites near permanent Grids 1 and 2. All animals collected were immediately frozen and transported to the laboratory.

In the laboratory stomach contents of animals were emptied into a Petri dish containing alcohol and examined under 120-power magnification. The material within the dish was sufficiently agitated to insure randomization. Twenty-five squares (13mm x 13mm) were systematically observed in each Petri dish. The relative frequency (R) of each of the three diet categories (I = Insects, S = Seeds, G = Greenery) was calculated for the two,most abundant,rodent species, the least chipmunk (*Eutamius minimus*) and the deer mouse (*Peromyscus maniculatus*), using the following formula:

NOTE: Area inside perimeter line = 6.93 acres

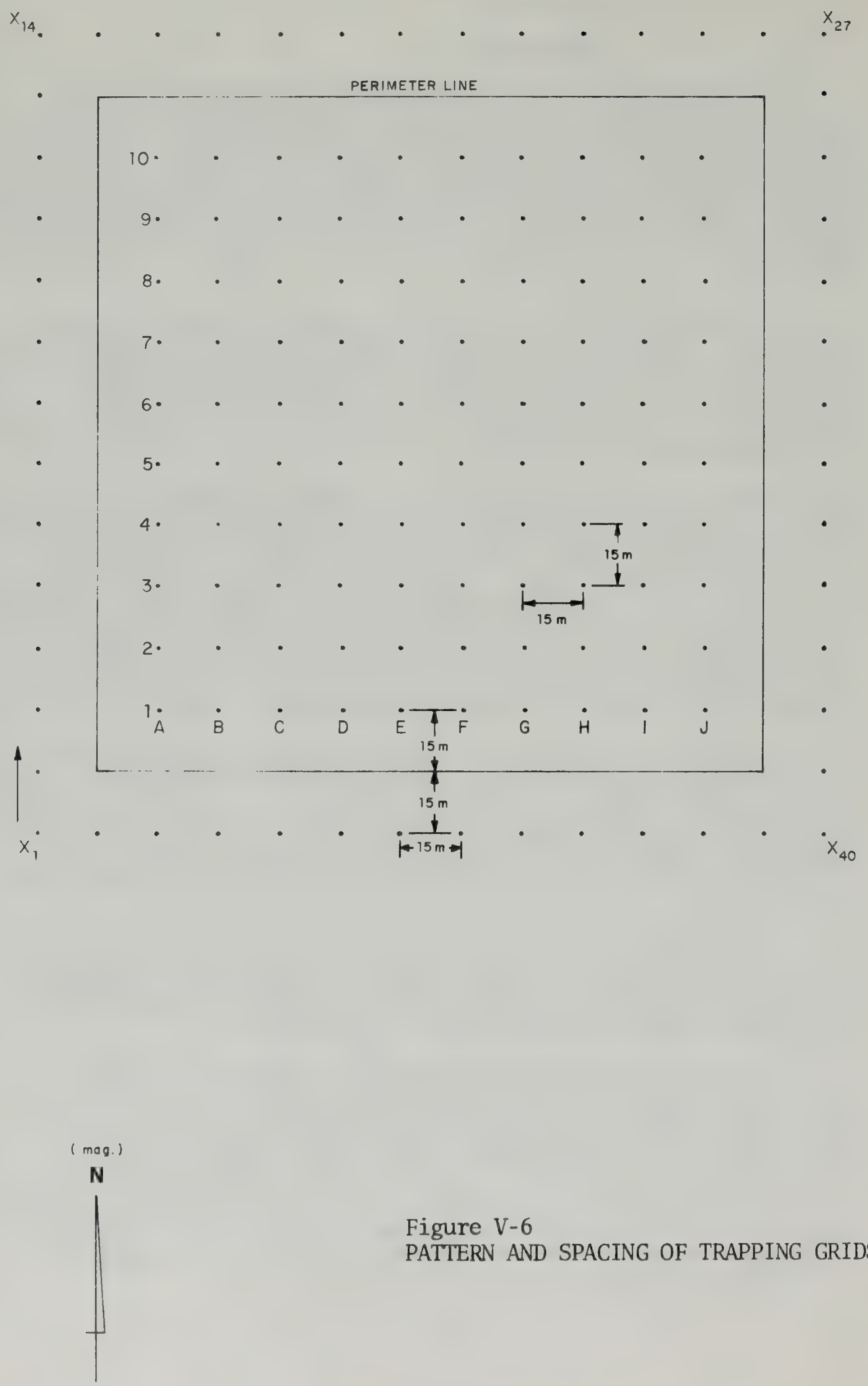


Figure V-6
PATTERN AND SPACING OF TRAPPING GRIDS 1 AND 2

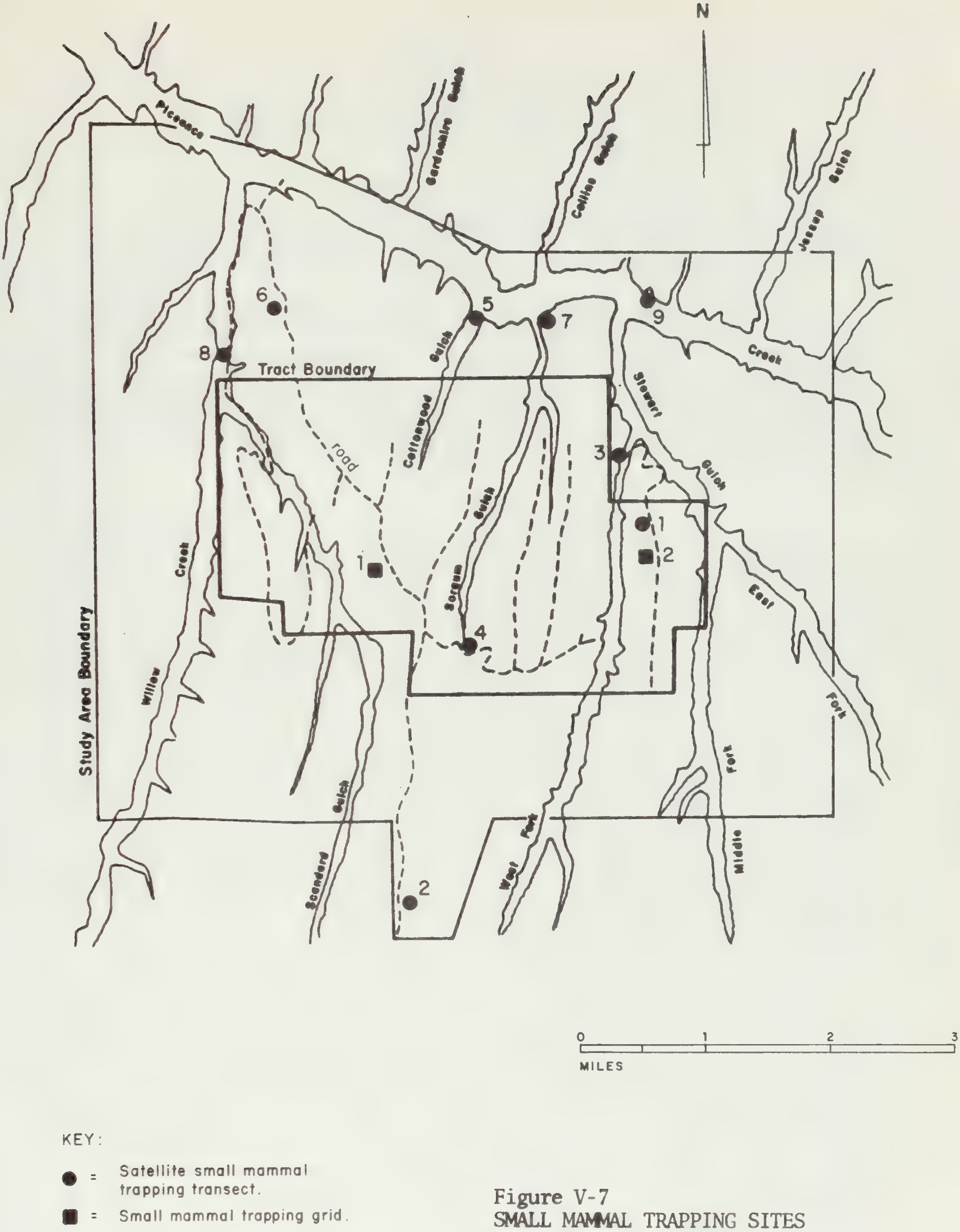


Figure V-7
SMALL MAMMAL TRAPPING SITES

$$R(C_1) = \frac{\sum_{n=1}^{N} F(C_1)}{\sum^{N} \{F(I) + F(S) + F(G)\}}$$

where F = the frequency of the diet category
where C_1= one of the three diet categories (repeated for each)
where N = the number of stomachs examined for that species of rodent.

The reproductive systems of all females collected in Museum-Special snap-trap lines during the period May 1975 through September 1975 are currently being examined. The horns of the uterus are examined for embryos and placental scars, both used to determine litter size. The number and size are recorded for embryos; the number and age (recent or old) of placental scars are recorded. The presence of recent placental scars will provide indications of the number of litter per year.

b. General Results

Trapping results reveal that the species numbers and species composition vary between the two sites. Eleven species have been captured at the chained site (Grid 1) and six species at the pinyon-juniper site (Grid 2) (Table V-7). Dense-line captures add two species at Grid 1 and one more species at Grid 2. The greater number of species captured at Grid 1 may be the result of additional habitat created by chaining operations at this location. The number of individuals within each species captured are tabulated in Tables V-7 and V-8.

A total of 16 small mammal species have been identified for the Tract. When total marked individuals on the large grids (Table V-7) are compared with total captures on the satellite grids (Table V-8), it is evident that the two most important species on Tract C-b, in terms of distribution and abundance, are the deer mouse and the least chipmunk. The minor species include the montane vole, long-tailed vole, Colorado chipmunk and golden-mantled ground squirrel.

(i) Grid 1 - Chained Pinyon-Juniper Site

From August 1974 through September 1975 a total of 1,595 individuals were captured over 4,864 trapnights from the grid lines and dense lines. In terms of population estimates for all species using two estimators, Hayne and EM-2, it is apparent that seasonal fluctuations result (Table V-9 and Figures V-8 and V-9). The Hayne population estimates for all species range from 31.3 animals in June 1975 to 132.3 animals in August 1975; spring and summer lows are followed by late summer highs. The highs in late summer apparently result from dispersal by subadults representing young from spring litters (See Quarterly Data Report #4 and #5).

Table V-7 NUMBERS OF SMALL MAMMALS MARKED ON THE PERMANENT GRIDS (EXCLUDING DENSE LINES) DURING THE PERIOD AUGUST 1974 THROUGH SEPTEMBER 1975

Scientific Name	Common Name	Grid 1	Grid 2
SORICIDAE			
Sorex cinereus	Masked shrew	2[2]	
Sorex vagrans	Vagrant shrew	1[2]	
SCIURIDAE			
Eutamius minimus	Least chipmunk	131	65
Eutamius quadrivittatus	Colorado chipmunk	c[1]	7
Spermophilus lateralis	Golden-mantled ground squirrel	14	10
GEOMYIDAE			
Thomomys talpoides	Northern pocket gopher	2	
HETEROMYIDAE			
Perognathus apache	Apache pocket mouse	20	c[1]
CRICETIDAE			
Lagurus curtatus	Sagebrush vole	1	
Microtus longicaudus	Long-tailed vole	c[1]	
Microtus montanus	Montane vole	43	1
Neotoma cinerea	Bushy-tailed wood rat	9	6
Peromyscus maniculatus	Deer mouse	143	155
Peromyscus truei	Pinyon mouse	1	
TOTAL		366	244

Note: Total number of animals captured on Grid 1 during the period August 1974 - September 1975 was 1595; total trap nights = 4864; trap success = 32.8%. Total number of animals captured on Grid 2 during the period August 1974 - September 1975 was 1,154; total trap nights = 4864; trap success = 23.7%.

1. Species captured on dense lines but not on the 10x10 grid.

2. Species captured on 10x10 grid but not marked.

Table V-8 NUMBERS OF SMALL MAMMALS TRAPPED IN SATELLITE GRIDS ON TRACT C-b. TOTALS ARE SUMMED OVER THE FIRST YEAR OF TRAPPING.

Scientific Name	Common Name	Satellite Grids* 1	2	3	4	5	6	7	8	9	Totals
SORICIDAE											
Sorex vagrans	Vagrant shrew			1							1
SCIURIDAE											
Eutamias minimus	Least chipmunk		29	33	8	27	33	17		8	155
Eutamias quadrivittatus	Colorado chipmunk		7		1	5	2			4	19
Spermophilus lateralis	Golden mantled ground squirrel		1	9		10	2			3	25
Spermophilus richardsoni	Richardson's ground squirrel				6						6
GEOMYIDAE											
Thomomys talpoides	Northen pocket gopher	1									1
HETEROMYIDAE											
Perognathus apache	Apache pocket mouse		1				1	8	4		14
CRICETIDAE											
Lagurus curtatus	Sagebrush vole		1		1		1		8		11
Microtus longicaudus	Long-tailed vole	1			1	3					5
Microtus montanus	Montane vole	11		6	3	1	1	4			26
Microtus pennsylvanicus	Meadow vole	1									1
Neotoma cinerea	Bushy-tailed wood rat		2	1			1				4
Peromyscus maniculatus	Deer mouse	31	49	40	54	47	39	66	65	43	434
ZAPODIDAE											
Zapus princeps	Western jumping mouse	2									2
TOTALS		47	90	90	74	93	80	95	77	58	704

*Location	Habitat Type
(1) Piceance Creek	Riparian/Willow-Hay Meadow
(2) West Stuart Creek	Valley Sagebrush/Rabbitbrush
(3) Tract Entrance Road	Mesa/Chained Pinyon-Juniper Mountain Shrub
(4) Lower Sorgum Gulch	Canyon Mouth/Sagebrush-Rabbitbrush
(5) Middle Sorgum Gulch	Canyon/Pinyon-Juniper-Mountain Shrub
(6) Upper Sorgum Gulch	Canyon/Grass-Mountain Shrub
(7) Lower Cottonwood Gulch	Canyon Mouth/Sagebrush-Rabbitbrush
(8) Willow Creek	Pond/Sagebrush-Hay Meadow
(9) Grid 2 Satellite	Hilltop/Pinyon-Juniper-Mountain Shrub

Table V-9 POPULATION ESTIMATES FOR SMALL MAMMALS ON PERMANENT TRAP GRIDS 1 & 2 FROM AUGUST 1974 THROUGH SEPTEMBER 1975. GRID SIZE = 2.72 HECTARES.

		August 1974		September 1974		May 1975		June 1975		July 1975		August 1975		September 1975	
Scientific Name	Common Name	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2
Peromyscus maniculatus	Deer mouse	23.9/[2] 18.9	42.5/ 32.8	68.8/ 51.9	64.4/ 77.1	10.7/ 10.5	3.3/ 6.0	11.3/ 9.7	23.4/ 6.2	15.8/ 17.6	13.0/ 6.0	26.6/ 30.2	20.1/ 22.4	16.1/ 33.9	13.6/ 6.5
Eutamius minimus	Least chipmunk	19.5/ 12.3	17.3/ 3.7	24.4/ 25.6	28.0/ 14.1	43.3/ 35.9	16.4/ 6.6	7.4/ 4.5	5/5[3]	5/5[3]	16.0/ 9.9	63.7/ 61.3	27.9/ 17.5	27.7/ 17.9	3/3[3]
Perognathus apache	Apache pocket mouse					3.3/ 2.9		3.6/ 4.0				11.7/ 4.0		6.9/ 6.4	
Microtus montanus	Montane vole	0.0/ 6.0		21.4/ 1.2		1.0/ 1.0		8.0/ 7.6		8.7/ 6.4		26.3/ 8.0	1/1[3]	6/6[3]	
Neotoma cinerea	Bushy-tailed wood rat			4.0/ 1.2							2/2[3]		1/1	1.8/ 1.5	
Eutamius quadrivittatus	Colorado chipmunk			1.0/ 1.0			3.0/ 3.0				1/1[3]		4/4[3]		
Spermophilus lateralis	Golden-mantled ground squirrel					4.3/ 5.3		1/1[3]		8/8[3]	5/5[3]	4/4[3]	3/3[3]		
COLUMN TOTALS		43.4/ 37.2	59.8/ 36.5	119.6/ 80.9	92.4/ 91.2	62.6/ 55.6	22.7/ 15.6	31.3/ 26.8	28.4/ 11.2	37.5/ 37.0	37.0/ 23.9	132.3/ 107.5	57.0/ 48.9	58.5/ 65.7	16.6/ 9.5

1. Total number of individuals estimated on the 10x10 grid - animals per hectare can be calculated by dividing the given estimate by 2.72- animals per acre can be caluclated by dividing the given estimate by 6.94.
2. Hayne estimate

   EM-2 estimate
3. Number captured on grid when no estimate is given by computer program.

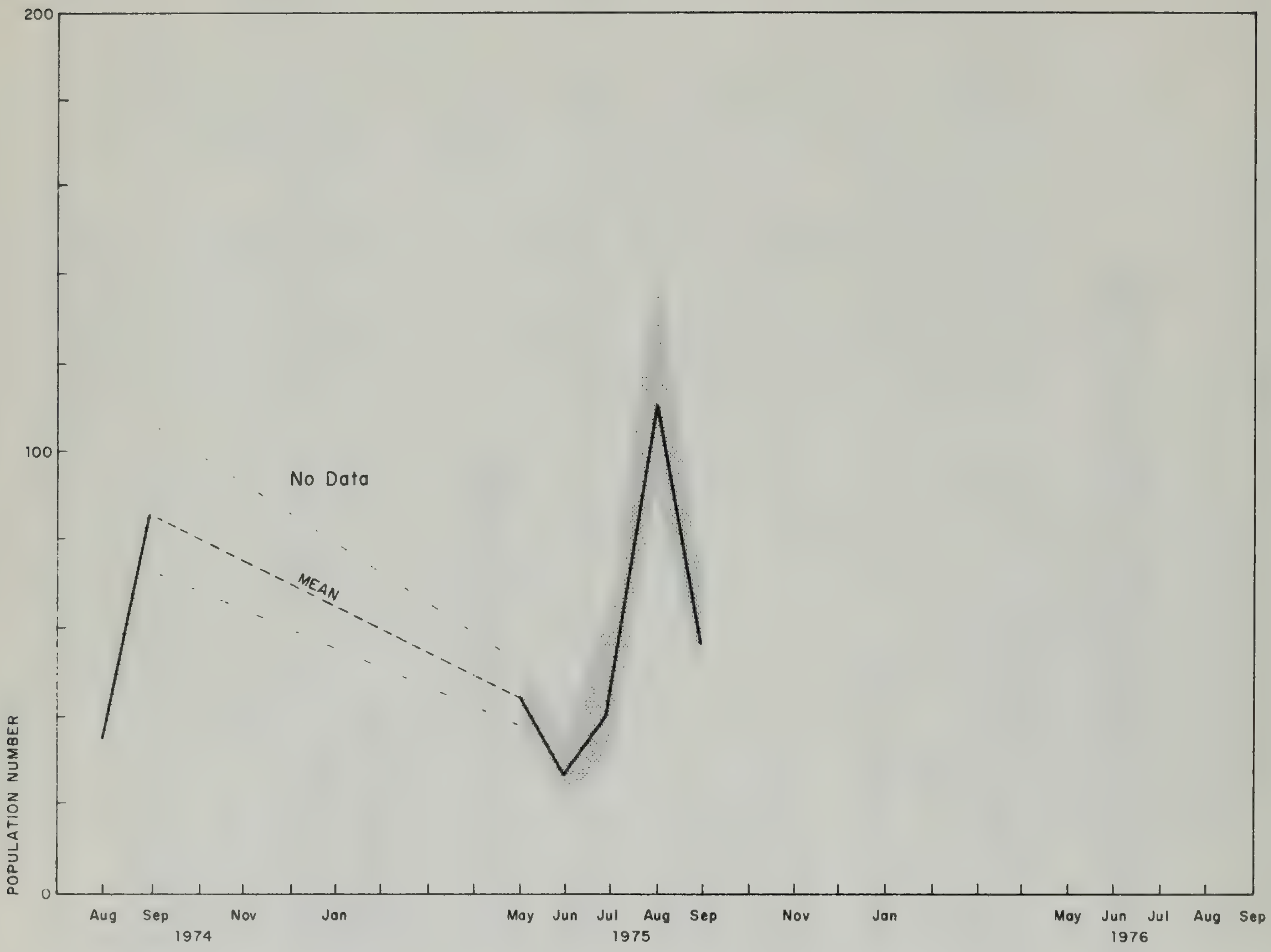


Figure V-8
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR ALL SPECIES COMBINED AT GRID 1 (chained pinyon-juniper rangeland). EM-2 ESTIMATOR

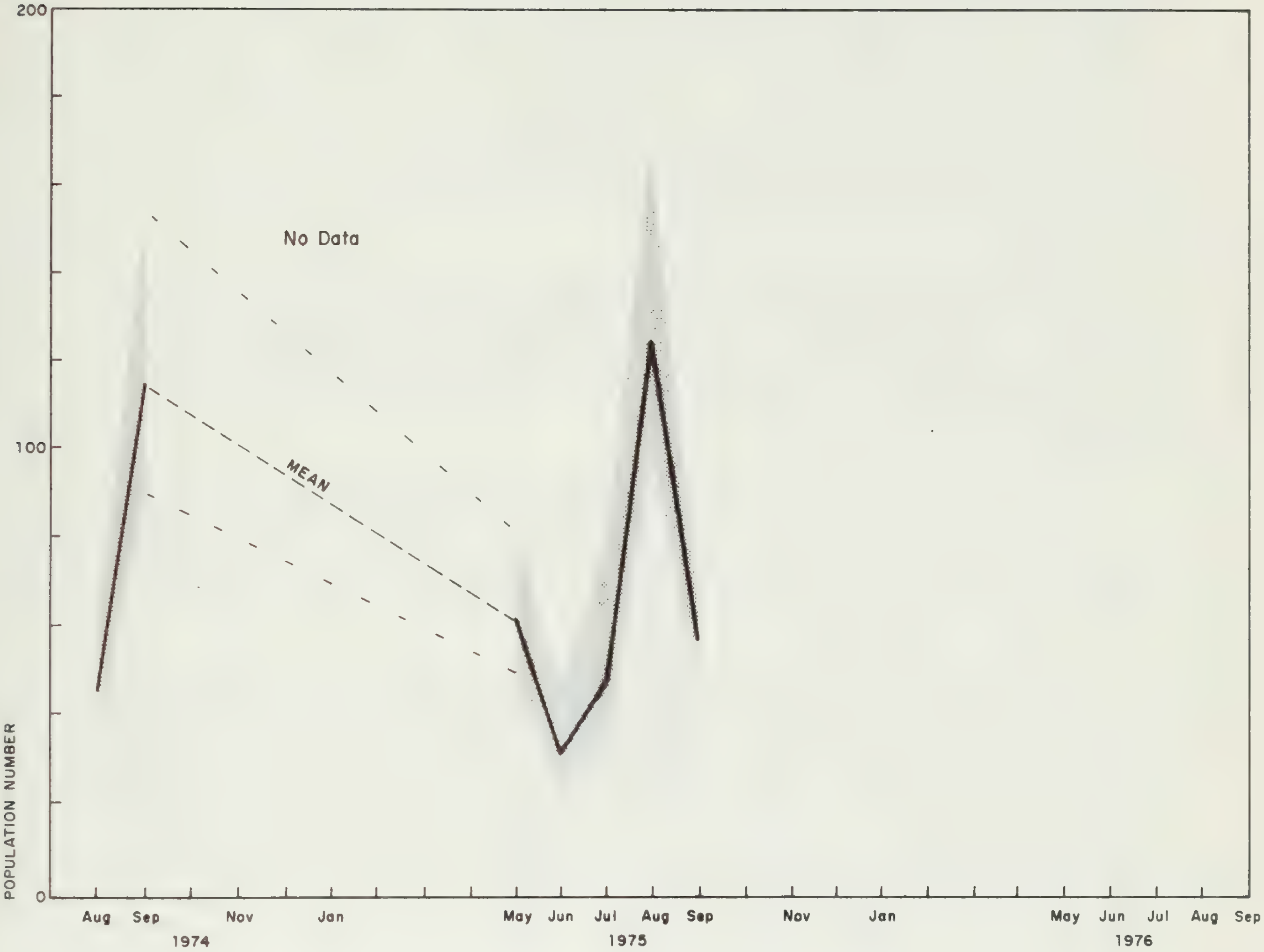


Figure V-9
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR ALL SPECIES COMBINED AT GRID 1 (chained pinyon-juniper rangeland). HAYNE ESTIMATOR

Deer Mouse (*Peromyscus maniculatus*)

Density

Deer mice were the most abundant animals on Grid 1 in the majority of trapping periods during 1974-75. This species exhibits both seasonal and annual fluctuations in density (Table V-9 and Figures V-10 and V-11). Averaging both density estimates (Hayne and EM-2) the density of deer mice per hectare was 7.6 in August 1974. The following month mean density had increased to 21.5 per hectare because of the dispersal of subadults from spring litters. During winter there was a decrease in density owing to predation and unfavorable weather conditions. By the end of August 1975 dispersal by subadults had resulted in a density of 10.1/ha,one-half the density for 1974.

The occurrence of peak densities during August of 1975, one month earlier than the 1974 peak, may be related to weather conditions since timing of peak densities is generally related to the initiation of breeding activity. In Colorado deer mice breed in the warmer months of the year with pregnancies occurring as early as April and as late as September (Lechleitner,1969).

The density estimates which fluctuate over summer months may also be related to weather conditions. During the May, June and July trapping periods irregular weather may have influenced trap success and resultant population estimates. The adverse effects of weather on small-mammal population estimates has been reported by Olsen (1973).

The annual fluctuation in the density estimate for the deer mouse, as found on Grid 1 (10.1/ha August 1975 - 21.5/ha September 1974), is documented in the literature. Larrison and Johnson (1973) found that deer mice populations regularly changed by factors of two or three and sometimes by a factor of ten from one year to the next. Chew and Turner (1974) classify factors that contribute to such fluctuations as either "density dependent" or related to food resources (primary productivity). They define density-dependent factors as behavioral interactions such as the incidence and duration of sexual activity, the number of young weaned per successful pregnancy and the survival of subadults.

Recapture Success

Recapture success influences the population estimate, estimates the turn-over rate and measures longevity. Recapture success also gives clues to behavioral patterns in the trappable species.

Of the 77 deer mice marked during August and September 1974 only six were subsequently recaptured. This indicates that at the end of the first year greater than 90 percent of these animals were absent from the Tract either through emigration or mortality. The greater percentage of this decline is attributed to mortality since only 52 new animals were marked from May to August 1975 and their combined recaptured success was 32 percent. Rapid turnover rates are common in deer-mouse populations and are documented in the literature (Olsen,1973).

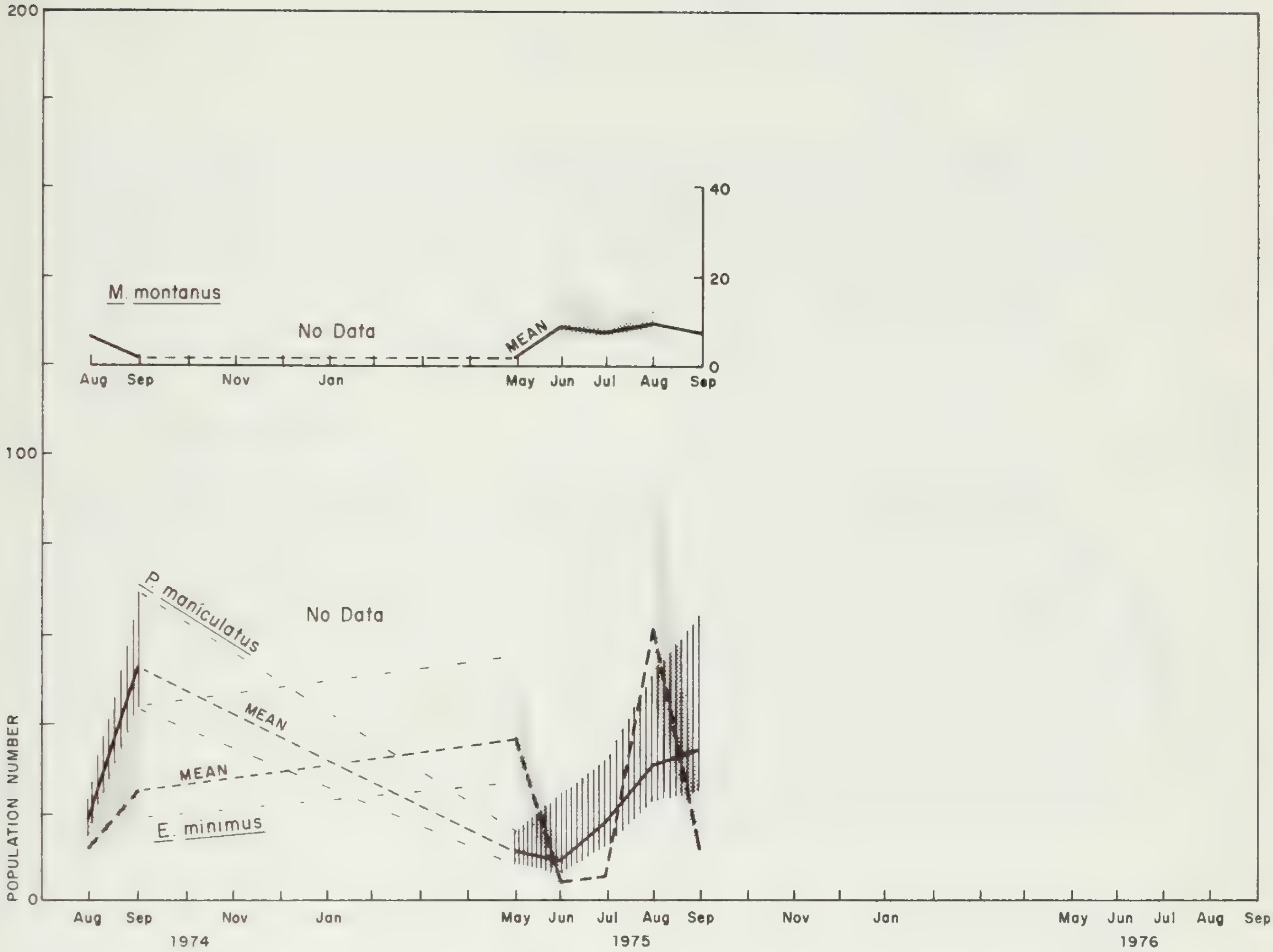


Figure V-10
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR THREE SPECIES AT GRID 1 (chained pinyon-juniper rangeland). EM-2 ESTIMATOR

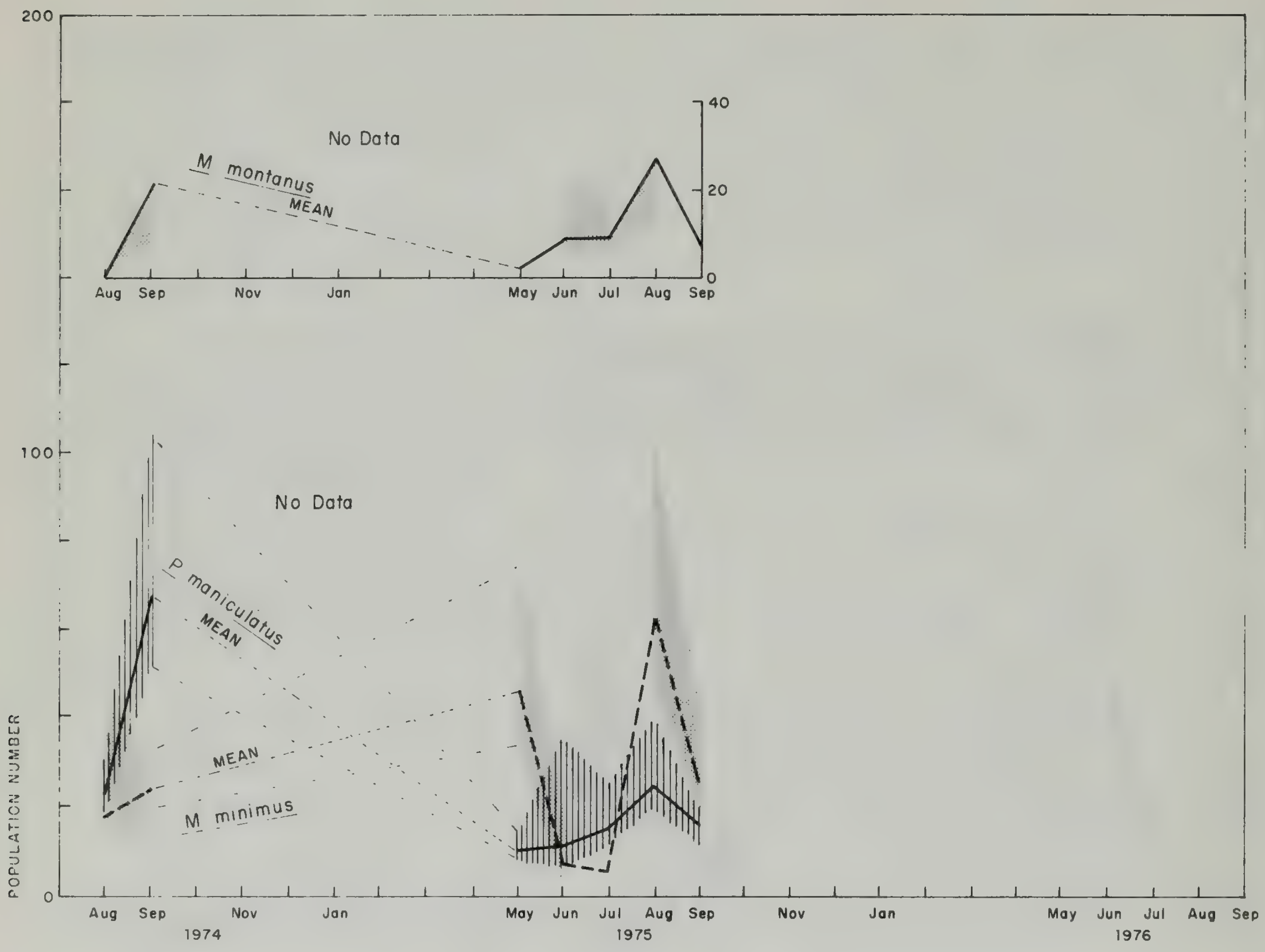


Figure V-11
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR THREE SPECIES AT GRID 1 (chained pinyon-juniper rangeland). HAYNE ESTIMATOR

Biomass

Live weights were determined for nine adult males, 16 non-reproductive females and three reproductive females captured in May 1975. This is documented in Table V-10. Although the sample size for reproductive females was small there is evidence that reproductive females weigh more than non-reproductives. Males contributed 30.4 gms/ha and females 51.3 gms/ha for a total of 81.7 gms/ha.

As shown in Table V-10, September 1975 live-weight determinations were from eight males, six non-reproductive females and five reproductive females. Reproductive females again showed an average increase over non-reproductive females. The average density of deer mice per hectare was 8.9. Males contributed 45.0 gms/ha and females 94.3 gms/ha for a total of 139.3 gms/ha of deer mice. Biomass at the end of September 1975 showed a 70 percent gain over the May 1975 estimate. Weights indicated that the majority of animals were new to the population and may have been animals representing spring litters.

Reproductive Activity

Reproductive activity for the deer mouse in Colorado generally commences in the spring and continues with varying intensity through summer (Lechleitner,1969). The initiation of reproductive activity on Grid 1 for the 1975 breeding season occurred in May when 85 percent of the males and 26 percent of the females were reproductive. The fluctuation in the percentages of reproductive males and females is shown in Figure V-12. The majority of these monthly fluctuations in reproductive activity may be attributed to factors such as primary productivity, population densities and temperature regimes as described above. However, the peak in female reproductive activity in August was in part owing to the large number of pregnant, subadult females, i.e., animals born in spring litters. The impregnation of subadult females is not unexpected and has been reported for other small mammal species (O'Farrell, et al. 1975).

Laboratory embryo counts indicate that population estimates for Grids 1 and 2 may be underestimated especially during periods when young are dispersing. Based upon a mean of 5.0 embryos per reproducing female (Table V-11), 90 percent fertility for the adult female population (Figure V-12) and a 50 percent survival between implantation and the time subadults enter the trappable population (Turner and McBrayer, 1974), the ratio of subadults recruited into the trappable population to adult females should be approximately 2.5 for the deer mouse. Density estimates show that the ratio of subadult deer mice to adult females was 1.0 in September 1974 and 0.81 in August 1975. These ratios are significantly lower than would be expected if 100% of the subadults entering the population had an equal probability of being trapped. It is likely that behavioral interactions between adults and subadults, i.e., dominance and territorial behavior exhibited by adults, prevented a large number of subadult animals from entering traps at the two permanent grids causing underestimation of density estimates.

Table V-10 LIVE WEIGHTS OF SMALL MAMMALS TRAPPED ON GRID 1, CHAINED PINYON JUNIPER DURING SEPTEMBER 1974, MAY 1975 AND SEPTEMBER 1975

	Deer Mouse (*Peromyscus maniculatus*)			Least Chipmunk (*Eutamias minimus*)		
	September 1974	May 1975	September 1975	September 1974	May 1975	September 1975
ADULT MALES						
Number weighed	0	9	8	1	36	16
Mean Weight, $\bar{x}$, grams	-	21.7	15.5	38	32.9	32.7
Range	-	17.0-27.0	11.0-21.0	-	28.0-44.5	30.0-36.0
Standard Deviation	-	4.0	3.9	-	4.3	1.9
95% Confidence Interval	-	$\bar{x} \pm 3.1$	$\bar{x} \pm 3.4$	-	$\bar{x} \pm 1.5$	$\bar{x} \pm 1.0$
ADULT FEMALES (Non-reproductive)						
Number weighed	0	16	6	0	30	5
Mean Weight, $\bar{x}$, grams	-	20.2	14.5	-	33.7	33.6
Range	-	15.5-26.5	12.0-21.0	-	21.5-40.0	30.0-37.0
Standard Deviation	-	3.5	3.6	-	3.8	2.5
95% Confidence Interval	-	$\bar{x} \pm 1.9$	$\bar{x} \pm 3.8$	-	$\bar{x} \pm 1.4$	$\bar{x} \pm 3.1$
ADULT FEMALES (Reproductive)						
Number weighed	0	3	5	0	20	0
Mean Weight, $\bar{x}$, grams	-	24.7	19.4	-	41.9	-
Range	-	23.0-27.5	14.0-29.0	-	26.5-53.0	-
Standard Deviation	-	2.5	5.8	-	6.8	-
95% Confidence Interval	-	$\bar{x} \pm 6.2$	$\bar{x} \pm 7.2$	-	$\bar{x} \pm 3.2$	-

NOTE: Biomass estimates given in text are computed by multiplying the average number of individuals/hectare(population estimate ÷ by appropriate conversion factor) by the average rodent live weight.

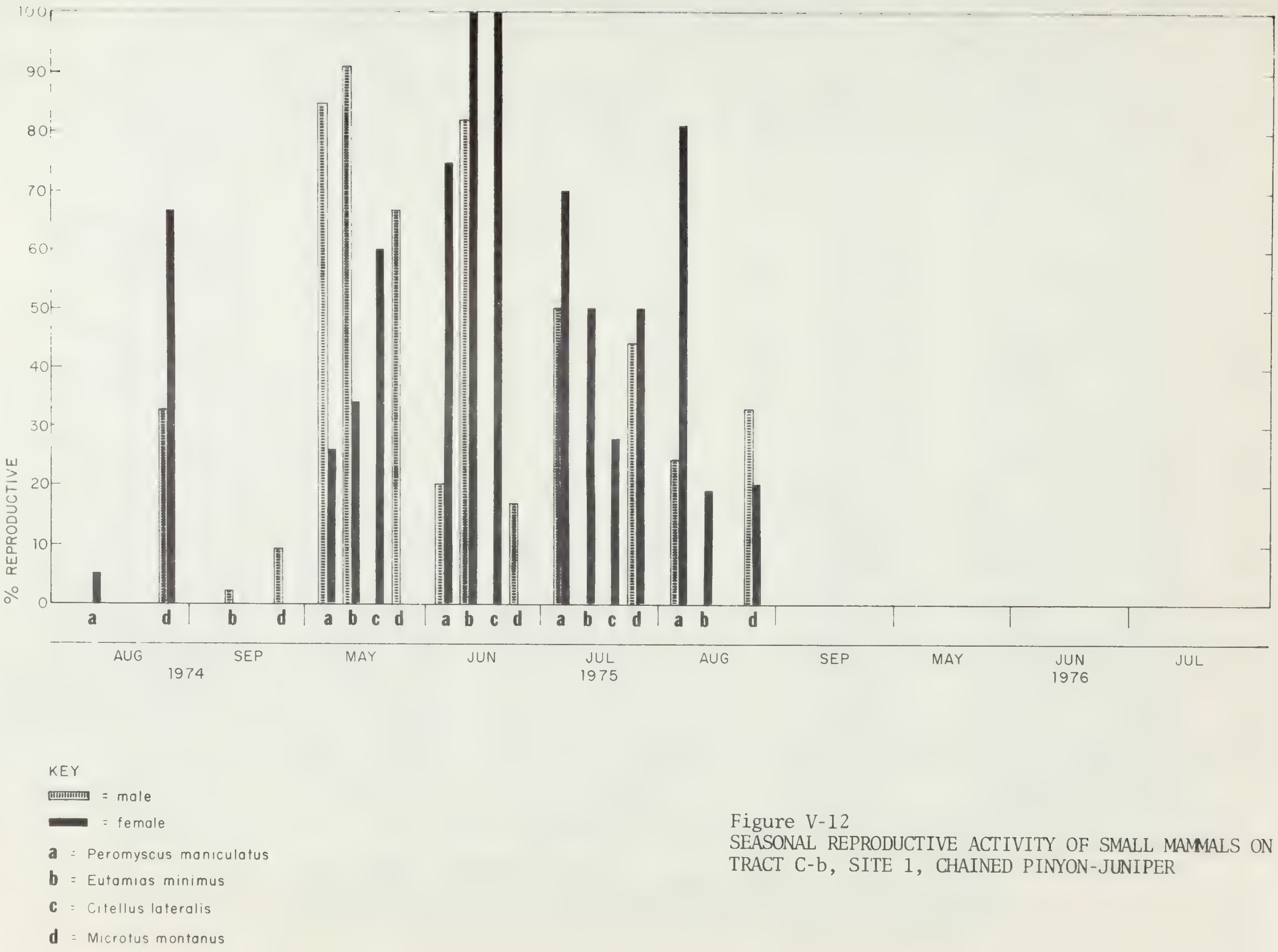


Figure V-12
SEASONAL REPRODUCTIVE ACTIVITY OF SMALL MAMMALS ON TRACT C-b, SITE 1, CHAINED PINYON-JUNIPER

Table V-11 MEASURES OF REPRODUCTIVE SUCCESS IN THE DEER MOUSE, Peromyscus maniculatus AND LEAST CHIPMUNK, Eutamias minimus ON TRACT C-b, MAY THROUGH SEPTEMBER 1975

	May	June	July	August	September	Total
GRID 1						
Deer Mouse (N=18)						
Placental Scars	-	-	-	24	-	24
Embryos	39	16	4	6	-	65
Least Chipmunk (N=13)						
Placental Scars	-	-	6	19	-	25
Embryos	44	-	-	-	-	44
GRID 2						
Deer Mouse (N=7)						
Placental Scars	-	6	14	-	-	20
Embryos	-	15	6	-	-	21
Least Chipmunk (N=1)						
Placental Scars	-	-	-	-	-	-
Embryos	-	-	-	-	-	-

Deer Mouse

Ave. No. Placental Scars: Site 1 - 12.0 (N=2); Site 2 - 6.7 (N=3)
Ave. No. Embryos: Site 1 - 5.0 (N=13); Site 2 - 5.2 (N=4)

Least Chipmunk

Ave. No. Placental Scars: Site 1 - 6.2 (N=4); Site 2 - 0 (N=0)
Ave. No. Embryos: Site 1 - 5.5 (N=8); Site 2 - 0 (N=0)

Food Habits

The deer mouse is an omnivore which consumes plant material, seeds, miscellaneous arthropods and other invertebrate animals as they become available (Johnson, 1961). The relative frequencies on use of these foods are given in Table V-12. The implication is that as primary production peaked in the summer and insect populations begin to decline, the importance of plant material in the deer mouse diet also increased. In September the consumption of seeds by the deer mouse increased over that of previous months probably because of the increased availability of seeds and a decrease in primary productivity and insect populations.

Habitat

Habitat preference for the deer mouse is probably the least restrictive of any species on the Tract. Their distribution is widespread throughout the chained pinyon-juniper rangeland and appears to show no particular preference for any one microhabitat. They occur in abundance along fallen trees, around shrubs and in the grassy patches.

Least Chipmunk (*Eutamius minimus*)

Density

The least chipmunk was the second-most abundant, small mammal at the chained site in the majority of trapping periods during 1974-75. Population estimates for the least chipmunk also fluctuate seasonally and annually as observed for deer mouse populations (Table V-9) averaging 5.7/ha in August 1974; increasing to 8.9/ha in September owing to the dispersal of subadults from spring litters, and averaging 14.1/ha in May 1975, a substantial increase over September 1974 estimates. This latter period represented the first time when the least chipmunk density-estimate was greater than the deer mouse estimate on Grid 1 (14.1/ha vs. 3.8/ha).

Immigration can be ruled out as a significant contributor to these high densities since it is assumed that emigration equals immigration. Winter mortalities are probably not significant since this species is relatively inactive over the winter. Additional recruitment to the population is the most likely explanation for high spring densities, since many subadult animals were trapped during this period, and additional subadults may have been prevented from entering the traps because of behavioral interactions with adults.

The lower densities in June (2.1/ha) and July (1.8/ha) were attributed to inclement weather during the survey periods. In August 1975, density (22.2/ha) had increased to the highest level ever recorded for the least chipmunk on Grid 1 and was 2.5 times greater than that of peak densities in 1974 (8.9/ha). This annual fluctuation may be related to primary production or density dependent factors as described for the deer mouse (Chew and Turner, 1974). An alternate explanation is that

Table V-12 RELATIVE FREQUENCIES OF DIET ITEMS IN STOMACHS OF THE DEER MOUSE AND LEAST CHIPMUNK FOR MAY THROUGH SEPTEMBER 1975

Species / Diet Item	May		June		July		August		September	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Peromyscus maniculatus										
Vegetation	19.2%	22.2%	31.7%	21.2%	32.2%	51.6%	47.2%	39.4%	49.0%	50.0%
Arthropods	79.1%	75.9%	68.3%	78.8%	67.8%	44.4%	50.9%	60.6%	0	0
Seeds	1.7%	1.9%	0	0	0	4.0%	1.9%	0	51.0%	50.0%
Stomachs Examined	6	4	3	4	3	6	3	4	1	1
Eutamias minimus										
Vegetation	50.7%	66.2%	67.9%	61.1%	63.9%	-	56.9%	60.6%	38.3%	-
Arthropods	48.6%	33.8%	32.1%	38.9%	29.6%	-	33.9%	21.6%	0	-
Seeds	0.7%	0	0	0	6.5%	-	9.2%	17.8%	61.7%	-
Stomachs Examined	3	2	1	1	3	-	7	6	3	-

the high density of least chipmunk in August 1975 may be related to direct or indirect competition with the deer mouse since the increase in chipmunk density coincided with a decrease in deer mouse density.

Recapture Success

During August and September 1974, 48 least chipmunks were marked and released. Twelve marked individuals were recaptured in the spring. This 75 percent reduction in the marked population by May 1975 compares to the deer mouse, spring, recapture success of only 1.2 percent. It is evident that winter inactivity enhanced over-winter survival of the least chipmunk.

From May through August 1975, 73 chipmunks were marked; 27.4 percent were still represented on the grid by the end of September. Including the animals marked in August and September 1974, the percentage of animals remaining on the grid by the end of September 1975 (16.7 percent) is more than two times higher than the percentage for the deer mouse (6.2 percent) and supplies further evidence of a lower turnover rate.

Biomass

In May 1975, live weights were determined for 36 males and 50 females (Table V-10): mean, male live-weight 32.9 $\pm$ 1.5 gms; non-reproductive females 33.7 $\pm$ 1.4 gms; and reproductive females 41.9 $\pm$ 3.2 gms. Total biomass for males totaled 177.7 gms/hectare, and for females, 314.5 gms/hectare.

During September 1975, 16 males (average weight 32.7 $\pm$ 1.0 gms) and five females (average weight 33.6 $\pm$ 3.1 gms) were examined. The total least chipmunk biomass of 267.5 gms/acre was divided into 166.7 gms for males and 100.8 gms for females.

The greatest biomass occurred in May 1975 when densities were 1.7 times higher than September 1975 densities and biomass was 1.8 times higher. The additional biomass was contributed by reproductive females which weighed approximately 8.6 gms more than non-reproductive individuals and comprised approximately 35 percent of the female populations.

Reproductive Activity

Male and female reproductive animals are shown on Figure V-12. The pattern of monthly changes in reproductive activity suggests that this species has a peak of reproductive activity in late spring and produces only one litter per reproductive season.

The mean number of young produced per litter was 5.8 based upon embryo counts and placental scars (Table V-11). This represents a slightly higher number than the mean number of young per litter for the deer mouse on Grid 1 and various other small mammal species (Franz, et al., 1972). However, a large number of young per litter would be expected for a species which produces only one litter per productive season such as the least chipmunk.

The incidence of placental scars from previous litters (30 percent of the females show placental scars resulting from spring 1974 litters) suggests a good carry-over of individuals from the previous year. This percentage of carry-over agrees closely with the percentage determined from recaptures (25 percent) noted above.

Food Habits

The relative frequencies of foods in the diet are given in Table V-12. In July when there was an apparent peak in arthropod populations, this item was utilized with greatest frequency. During the month of August 1975, after flowering had been completed for most plant species and seed set had been accomplished, seed items increased in relative frequency. Johnson (1961) reports chipmunks to be opportunistic feeders.

Habitat

The least chipmunk was the second-most-abundant small mammal in the majority of trapping periods on the Tract and has been encountered in most habitats. At the chained site this species is abundant in and around fallen trees and shrubs. Where the chained rangeland borders on the pinyon-juniper woodland to the west, the least chipmunk is sympatric with the Colorado chipmunk.

(ii) Grid 2 - Pinyon-Juniper Woodland Site

For the year August 1974 through September 1975 a total of 1,154 individual small mammals have been captured over 4,864 trapnights from the grid lines and dense lines. In terms of population estimators, Hayne and EM-2, it is apparent that seasonal and annual fluctuations occur similarly to those observed on Grid 1 (Table V-9 and Figures V-13 and V-14). The Hayne population estimates for all species for the grid range from 28.4 animals in June 1975 to 57.0 animals in August 1975. Spring and summer lows are followed by late summer highs and are apparently the result of dispersal by subadults representing young from spring litters.

Deer Mouse (Peromyscus maniculatus)

Density

Fluctuations in density for the deer mouse at the pinyon-juniper site were very similar to fluctuations at the chained site (Table V-9). Density estimates were highest in September 1974 (25.2 animals/hectare); during winter there was a decrease in density (1.7/ha - May 1975) because of predation and unfavorable weather conditions; and by August 1975 dispersal by subadults had resulted in a density of 7.6/ha, approximately 0.33 of the peak density recorded in September 1974. This decline, somewhat higher than annual fluctuations reported, (Terman, 1968), may be related to factors discussed on Grid 1.

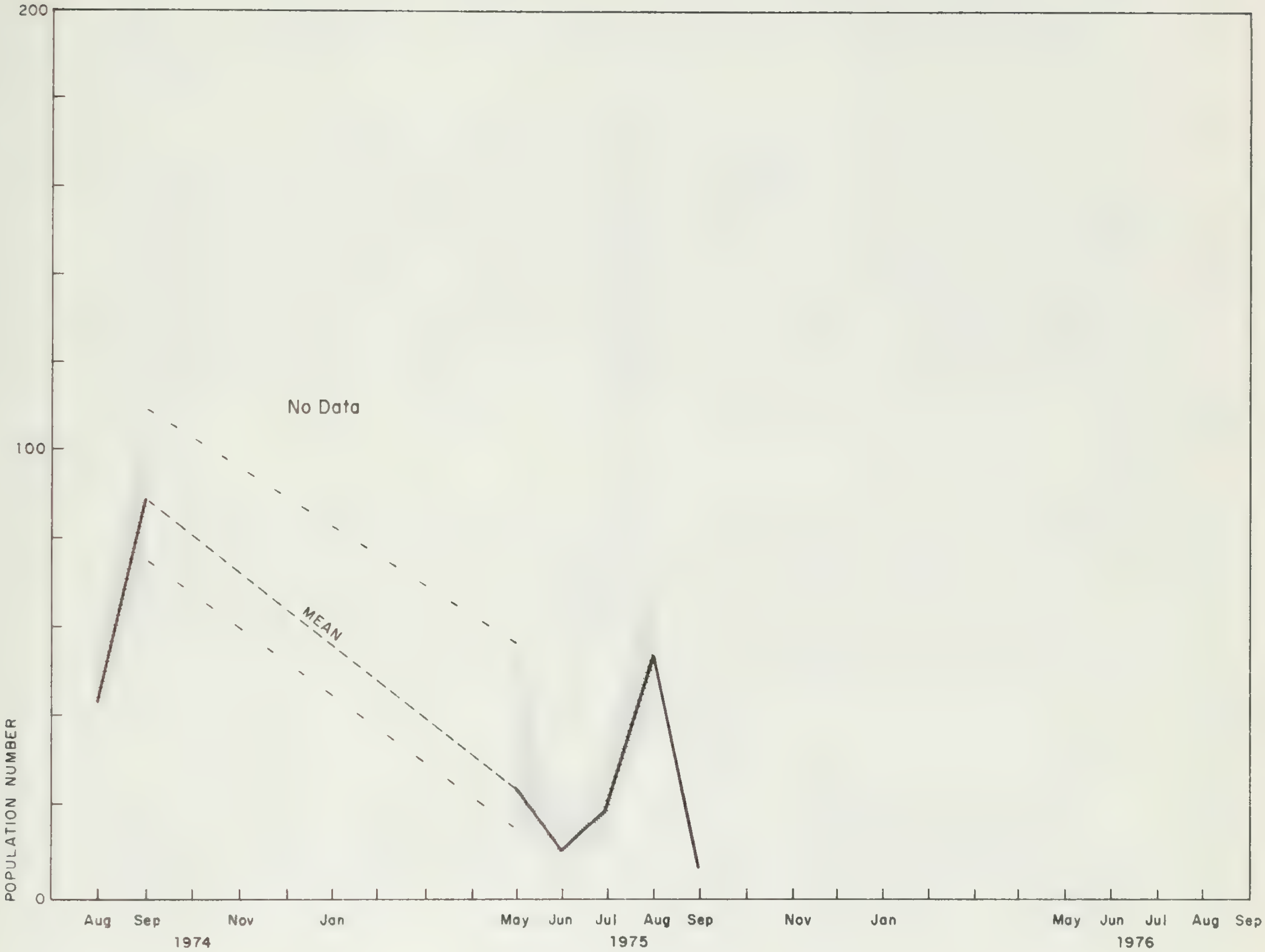


Figure V-13
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR ALL SPECIES COMBINED AT GRID 2 (pinyon-juniper woodland). EM-2 ESTIMATOR

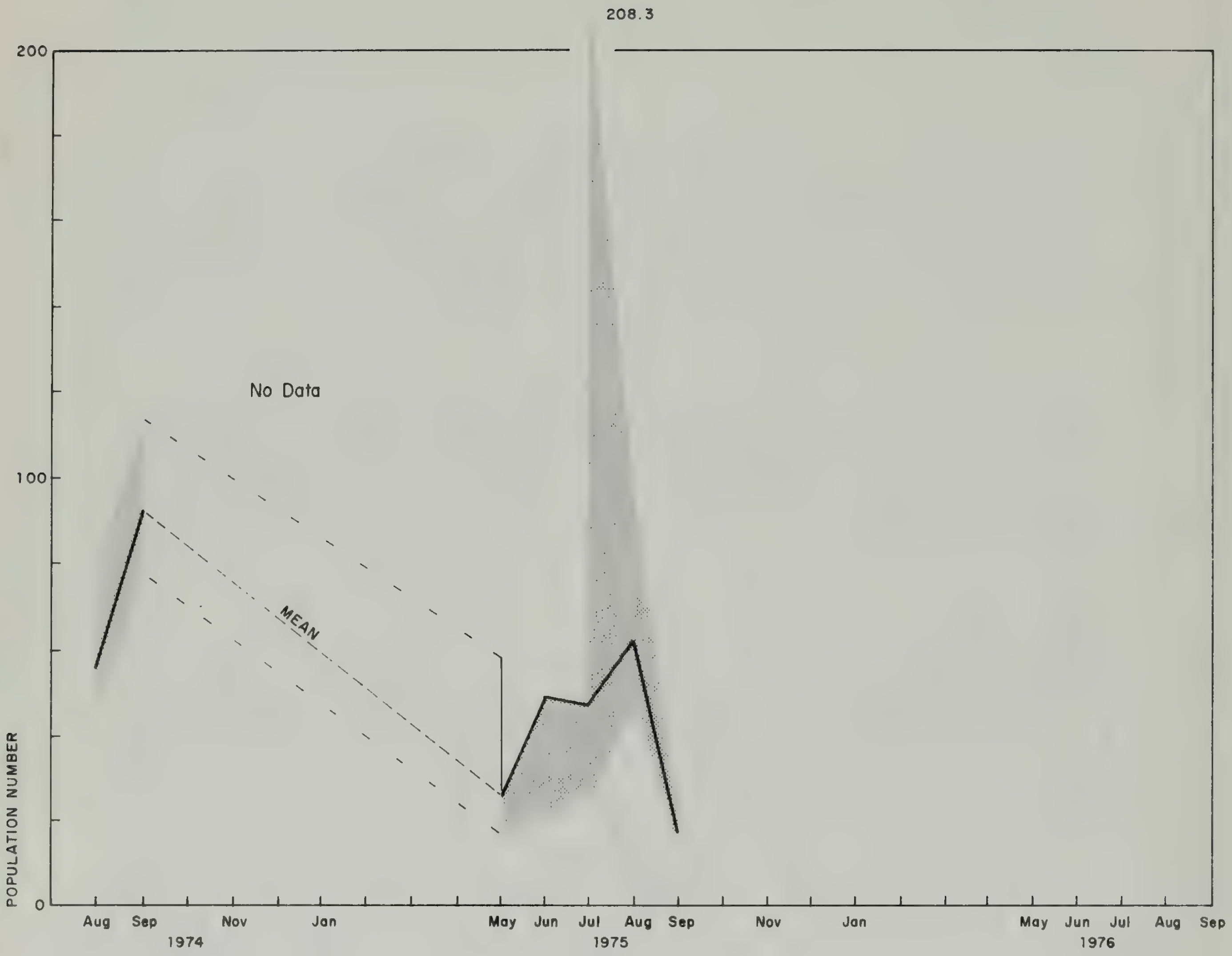


Figure V-14
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR ALL SPECIES COMBINED AT GRID 2 (pinyon-juniper woodland). HAYNE ESTIMATOR

Recapture Success

During August 1974, 41 deer mice were marked at Grid 2. Eleven of these individuals were recaptured the following month; only four of the 41 were recaptured through the 1975 trapping season; and by August 1975 none of the original 41 were seen again. Sixty-three deer mice were marked in September 1974 and only one of these individuals was recaptured through 1975.

From May through July, 22 new deer mice were marked. Their combined recapture success in August 1975 was 12.5 percent. Of the 19 new animals marked in August 50 percent were recaptured the following month. Fifty-one animals were marked during the 1975 year which is approximately one-half those marked in 1974. Density estimates in August 1975 were also about one-half the August 1974 estimates. Approximately 10 percent of the deer mice captured in 1975 were 1974 animals. All this suggests that the deer mouse population is primarily an annual population, similar to the population on Grid 1, with the majority of the mice being replaced by new individuals each year.

Biomass

During September 1974 live weights were determined for 24 male and 16 female deer mice (Table V-13). The average density of deer mice (25.2/ha) represented a total biomass value of 574.0 gms/ha of which males contributed 240.6 gms/ha and females 333.4 gms/ha. In May 1975 male biomass was 6.5 gms/ha and female biomass 28.7 gms/ha for a total mean biomass of 35.2/ha. This represents a 16-fold decrease in biomass over the winter and is 232 percent less than the biomass estimate for the chained site for the same time period.

During September 1975 the total average biomass of 17 males, 11 non-reproductive females and one reproductive female was 68.4 gms/ha with 42.7 gms/ha contributed by males and 25.7 gms/ha contributed by females (See explanation on Table V-13). This total average biomass represents only nine percent of the original biomass present the previous September and reflects a decline in the population level of deer mice on Grid 2 as illustrated by lower density estimates.

A comparison of average live weights for animals examined in the spring (May 1975) against animals examined in the fall (September 1975) indicates that average live weight per animal was higher in the spring. Since the summer season (in temperate climates) generally affords the most favorable conditions for growth in terms of photoperiod, temperature and primary productivity (Smith et al., 1974), these results were unexpected. However, it is likely that the lower-than-anticipated average live weights in September were the result of large numbers of subadults in the population. If these animals were trapped shortly after their independent foraging was initiated, their genetic limits for growth probably had not been met (Smith et al., 1974) and the average biomass per animal would necessarily be lowered owing to low-weight subadults.

Table V-13 LIVE WEIGHTS OF SMALL MAMMALS TRAPPED ON GRID 2, PINYON-JUNIPER DURING SEPTEMBER 1974, MAY 1975 AND SEPTEMBER 1975

	Deer Mouse (*Peromyscus maniculatus*)			Least Chipmunk (*Eutamias minimus*)			Colorado Chipmunk (*Eutamias quadrivittatus*)		
	September 1974	May 1975	September 1975	September 1974	May 1975	September 1975	September 1974	May 1975	September 1975
ADULT MALES									
Number weighed	24	11	17	8	11	1	7	7	1
Mean Weight, $\bar{x}$, grams	23.0	21.7	14.3	42.2	31.5	24.0	53.6	52.4	50.0
Range	10.0-30.0	18.0-25.0	9.5-21.0	35.0-55.0	29.0-34.0	-	45.0-70.0	43.0-58.0	-
Standard Deviation	4.8	2.3	3.4	7.5	1.9	-	8.0	5.1	-
95% Confidence Interval	$\bar{x} \pm 2.0$	$\bar{x} \pm 1.5$	$\bar{x} \pm 1.7$	$\bar{x} \pm 6.3$	$\bar{x} \pm 1.3$	-	$\bar{x} \pm 7.4$	$\bar{x} \pm 4.7$	-
ADULT FEMALES (Non-reproductive)									
Number weighed	16	3	11	6	7	0	1	0	0
Mean Weight, $\bar{x}$, grams	19.2	19.0	13.5	35.7	36.6	-	50.0	-	-
Range	10.0-30.0	17.0-22.0	9.0-20.0	32.0-40.0	32.0-41.0	-	-	-	-
Standard Deviation	4.8	2.6	3.1	2.6	3.2	-	-	-	-
95% Confidence Interval	$\bar{x} \pm 2.6$	$\bar{x} \pm 6.5$	$\bar{x} \pm 2.1$	$\bar{x} \pm 2.7$	$\bar{x} \pm 3.0$	-	-	-	-
ADULT FEMALES (Reproductive)									
Number weighed	0	8	1	0	5	0	0	6	0
Mean Weight, $\bar{x}$, grams	-	21.3	21.0	-	34.2	-	-	59.7	-
Range	-	18.5-25.0	-	-	30.0-39.5	-	-	56.0-65.0	-
Standard Deviation	-	2.4	-	-	3.1	-	-	3.1	-
95% Confidence Interval	-	$\bar{x} \pm 2.0$	-	-	$\bar{x} \pm 3.8$	-	-	$\bar{x} \pm 3.3$	-

NOTE: Biomass estimates given in text are computed by multiplying the average number of individuals/hectare: (population estimate ÷ by appropriate conversion factor)by the average rodent live weight.

Reproductive Activity

In August 1974 no male reproductive activity was observed while 16 percent of the female population was reproductive (Figure V-17). In May at the start of the 1975 survey period 85 percent of the males and 64 percent of the females were already reproductive. This is similar to reproductive activity for the chained site. Male activity decreased over the summer to 10 percent in August while female activity remained high (91 percent in July and 60 percent in August). In contrast to 1974 the indication is that a greater proportion of reproductive females produced two litters. Reproductive subadults may have contributed to this late season peak in reproductive activity.

Food Habits

Insects formed a large proportion of the diet of the deer mouse in May and June but less so in July (Table V-12). Plant material shows an inverse relationship increasing in relative frequency to 55.7 percent in July. Seeds constituted a major diet item in September (50 percent). Apparently the preference for diet items is regulated by the relative availability of various food sources as discussed in previous sections.

Habitat

The habitat for the deer mouse at this study site is a pinyon-juniper woodland mixed with an understory of sagebrush, serviceberry, mountain mahogany and other shrubs.

Least Chipmunk (*Eutamius minimus*)

Density

The least chipmunk was the second-most-abundant small mammal at the pinyon-juniper site in the majority of trapping periods. Their population estimates also fluctuate seasonally and yearly (Table V-9 and Figures V-15 and V-16). Averaging both density estimates the density of least chipmunks on Grid 2 was 3.75/ha in August of 1974. In September 1974 mean density had increased to 7.5/ha owing to the dispersal of subadults from spring litters. The following spring a mean density estimate of 4.1/ha represented a decrease in the population because of over-winter mortality. Density estimates remained low in June and July. In August 1975 the density estimate rose to 8.1/ha, again attributed to the dispersal of subadults, and little change from the peak density reported in September 1974 (7.5/ha).

Recapture Success

Ten individual least chipmunks were captured and marked in August 1974. The following month six were recaptured. During 1975 at least four were recaptured and one animal was still present in September 1975. Of the 28 individuals marked in September 1974 three were still present in August 1975. During this month 12 percent of all previously marked

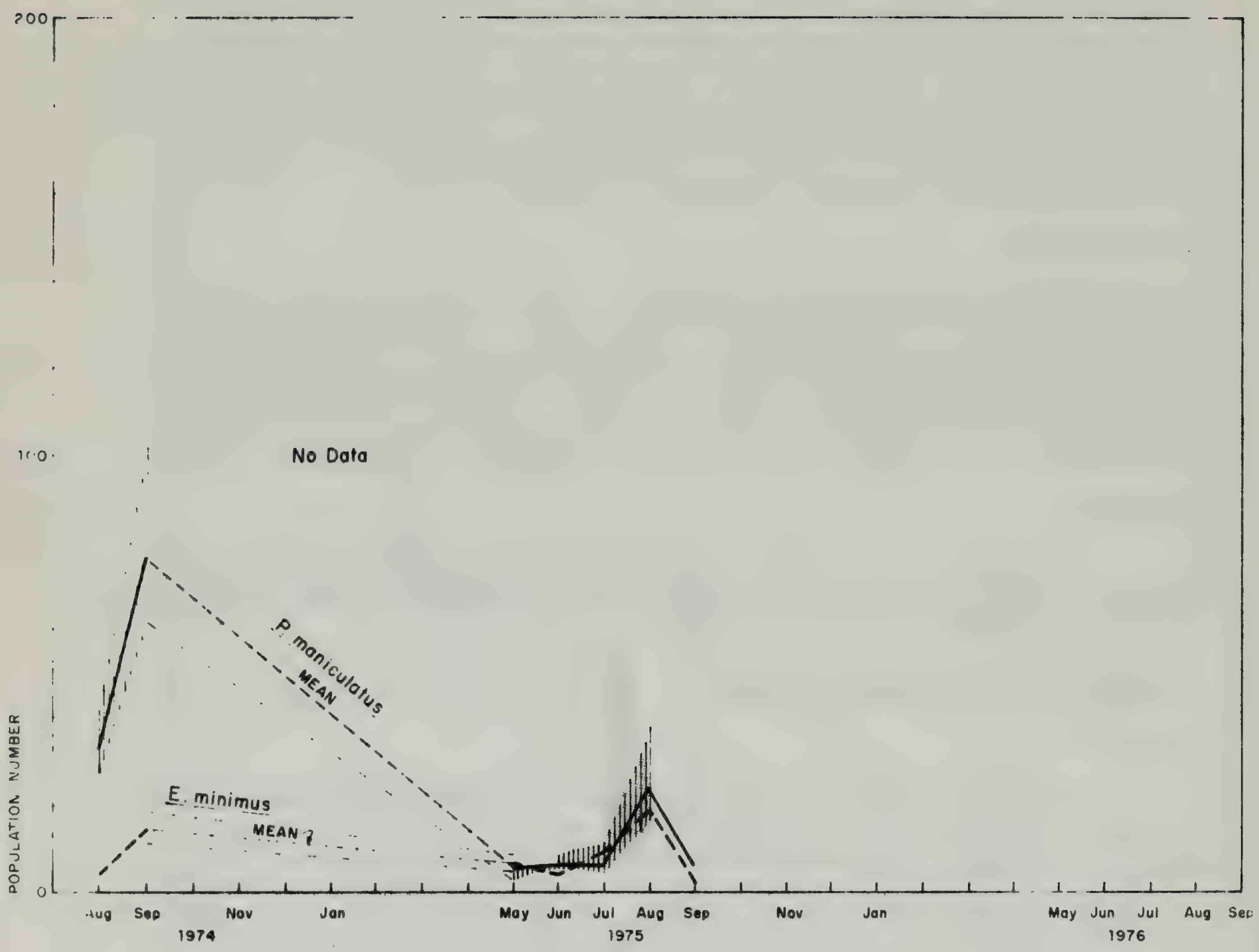


Figure V-15
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR TWO SPECIES AT GRID 2 (pinyon-juniper woodland). EM-2 ESTIMATOR

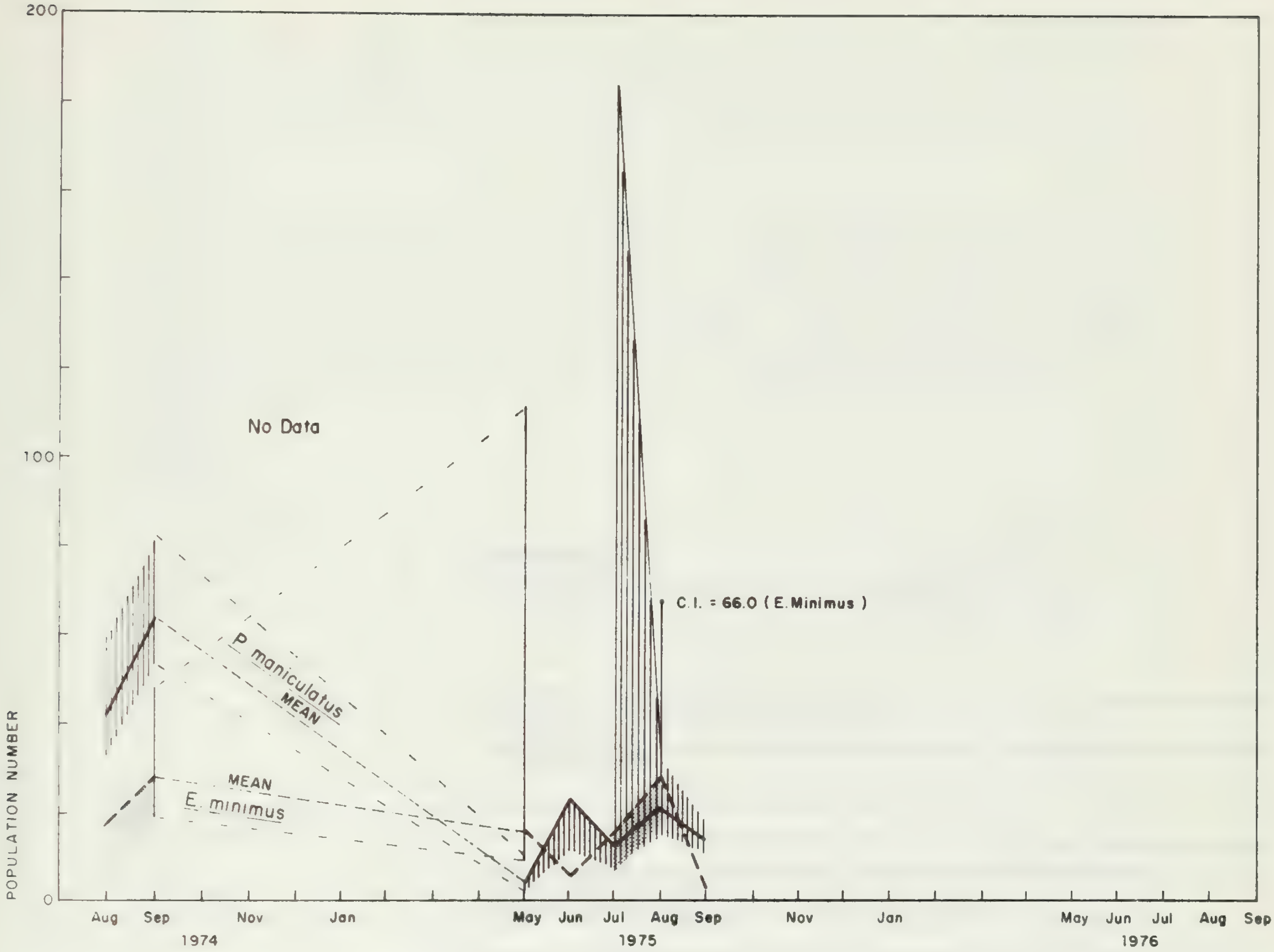


Figure V-16
POPULATION ESTIMATES WITH 95% CONFIDENCE BELTS FOR TWO SPECIES AT GRID 2 (pinyon-juniper woodland). HAYNE ESTIMATOR

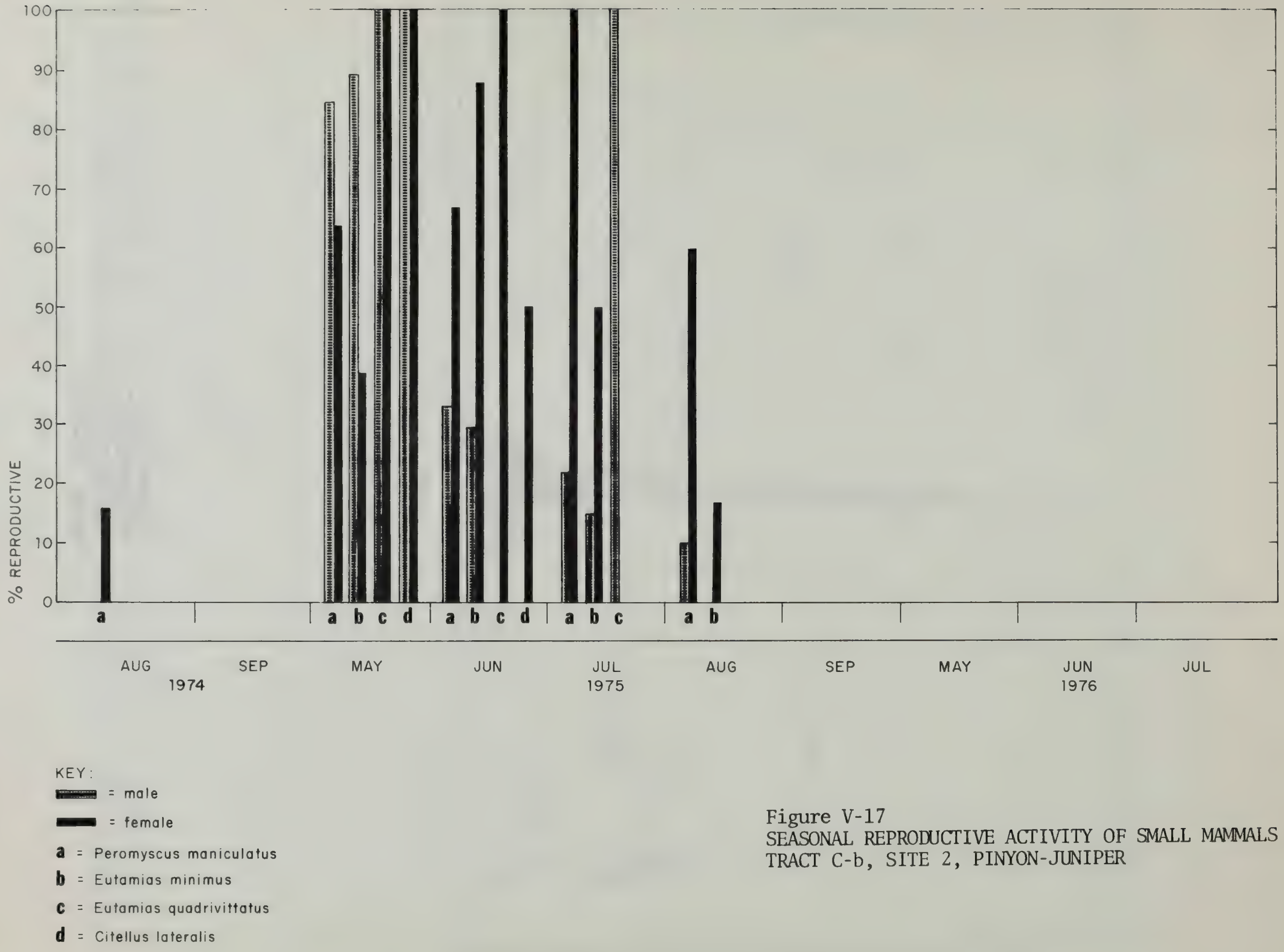


Figure V-17
SEASONAL REPRODUCTIVE ACTIVITY OF SMALL MAMMALS ON TRACT C-b, SITE 2, PINYON-JUNIPER

individuals were still present on the grid. This percentage is only slightly higher than the deer mouse figure of 8.3 percent and indicates that the turnover rate for least chipmunk and deer mouse was similar on Grid 2 to that on Grid 1.

Biomass

The live weights for the chipmunks in September 1974 include both the least chipmunk and the Colorado chipmunk (Table V-13). Total chipmunk biomass was 320.0 gms/ha; males averaged 180.5 gms/ha and females averaged 139.5 gms/ha. Total biomass was 90 percent that of biomass at Grid 1.

The May 1975 live weight determinations included eleven males and twelve females. Total biomass was 140.9 gms/ha, which was 3.5 times less than the total chipmunk biomass per hectare at the chained study site. This difference results from a higher density of least chipmunks at the latter site during May 1975 since mean live weights per animal were essentially the same. No biomass estimates were available for September 1975 since only one chipmunk was weighed (24.0 gms).

Reproductive Activity

The reproductive cycle for both males and females at this study site was similar to that at the chained site, i.e., males became reproductive first and then gradually decreased in activity through the year; females peaked in June but were still reproductive in August. There was no change in the proportion of reproductive females when comparing August 1974 to August 1975 (Figure V-17).

Food Habits

A large percentage of the diet during the months of May and June 1975 was green plant material (Table V-12). Arthropods were consumed in lesser amounts and composed the remainder of the least chipmunk diet. In August 1975 the frequency of seeds had increased and the relative frequency of insects in the diet had declined. The data suggest that food availability determines food preference for opportunistic consumers such as the least chipmunk.

Habitat

The pinyon-juniper woodland study site is characterized by an overstory of mature and sapling pinyon pines and juniper trees. The understory consists of big sagebrush, mountain mahogany, serviceberry, antelope bitterbrush and snowberry. Grasses are very sparse and the soils are shallow. Where the woodland extends to the xeric slopes and rimrock the Colorado chipmunk becomes more abundant and the least chipmunk less so.

(iii) Miscellaneous Small Mammals

Species of small mammals trapped with varying degrees of regularity at the two permanent grids and satellite grids are noted in Tables V-8 and V-9. Data are too meager to note trends in seasonal fluctuations or

densities for the majority of these species. Several are probably important members of the ecosystem specifically as prey species and herbivores.

Montane Vole (*Microtus montanus*)

The montane vole was captured with fair regularity at Grid 1 and at satellite grids in Piceance and Willow Creek valleys. (Only one was captured at Grid 2). The density estimate on Grid 1 was 4.0 voles/ha in September 1974 (Table V-9). Additional trapping in the period October - December 1974 at satellite grids in Piceance Creek and Willow Creek valleys indicated that their populations peaked during this time. In the spring of 1975 their relative abundance declined at both the satellite grids and Grid 1 to 0.36/ha (May 1975). Following these population lows, densities recovered somewhat on Grid 1 in August (6.1/ha) but declined in September to 2.1/ha. At the satellite grids the relative abundance of voles remained low throughout the summer and early fall. By the end of September vole populations were low over the entire Tract in direct contrast to the situation in 1974 when populations were high during these months. Vole populations remained low on satellite grids through November 1975.

Based upon previous studies of vole populations (Golly, 1961; Hoffman, 1958) several factors may have influenced the above seasonal fluctuations. These factors include competition for space and resources, natality, mortality and predation. In the spring of 1974 vole populations were probably low and resources were abundant, thus competition for space and resources was probably insignificant. Because of high birth rate throughout the summer and early fall the population increased rapidly. Breeding may have continued through the winter (1974-75) at a reduced rate. As a result of predation by wintering raptors, weasels and other mammalian predators and low winter natality (Quarterly Data Reports #2 and #3) populations had declined significantly by May 1975.

Fluctuations in numbers from year to year (multi-annual), as evidenced by peak vole densities in fall of 1974 and minimum densities in the fall of 1975, are cycles as distinct from seasonal fluctuations (Hoffman, 1958).

On Tract C-b wintering raptors relied heavily on voles in the 1974-75 period. If the vole population remains low throughout the current winter (1975-76), shifts in prey species are expected. It is anticipated that raptors would utilize other abundant species, such as deer mice, that remain active throughout the winter.

Golden-Mantled Ground Squirrel (*Spermophilus lateralis*)

The golden-mantled ground squirrel was trapped on Grids 1 and 2 at five of the nine satellite grids. This species occurred in all habitat types over the Tract with the exception of riparian areas and valley-floor hay meadows. Although their distribution was widespread, specific habitat types supported the greatest number of squirrels. These habitat types included rocky canyon slopes with pinyon-juniper and mixed mountain

shrub, represented by satellite 5 and ridgetops with chained pinyon-juniper, represented by Grid 1 and satellite grid 3. This preference of habitat was described by Lechleitner (1969) and McKeever (1964) who found this species occurring in either rocky areas or meadows or open coniferous forests. Apparently the preference for open areas was related to the larger amounts of herbaceous vegetation associated with an open canopy.

Density estimates for the golden-mantled ground squirrel on Grid 1 (Table V-9) were: 1.7 animals/ha in May 1975, 0.04/ha in June, 3.2/ha in July and 1.4/ha in August. Based upon these densities, this species represents the fourth-most-abundant small mammal species of Tract C-b. The seasonal activity pattern is distinct from the other abundant, small mammals since it is the only species with a period of true hibernation. The ground squirrel was only observed above ground during the months of April through October (Table V-9 and general observations). Based upon previous studies (McKeever, 1974) it is likely that the first animals observed in the spring were sexually active males. Reproductive females generally appear later in May and June and reproductive activity is generally concentrated in the spring when the annual liter is produced (McKeever, 1964). Peak densities in July were probably the result of recruitment to the population of young of the previous year since they generally appear above ground during this month. Above-ground activity decreased during September and October resulting in lower population estimates. After sufficient quantities of subcutaneous fat are accumulated, animals enter into hibernation. By November-December the majority of golden-mantled ground squirrels have entered hibernation.

During the spring and early summer, when leaves are young and succulent, herbaceous vegetation probably constitutes the main food category. On Tract C-b, as the season advanced and herbaceous vegetation diminished, it was evident that pinyon nuts became an important part of the ground squirrel's diet. By August-September, when pinyon nuts were most abundant, numerous piles of husked pinyon cones were observed over the Tract. These observations suggest that the ground squirrel, as the deer mouse and chipmunk, consumed different diet items in proportion to availability, thereby producing a seasonal pattern in food habits.

Apache Pocket Mouse (*Perognathus apache*)

The Apache pocket mouse was trapped with regularity on Grid 1 and satellite grids 7 and 8. The habitat of these locations was characterized by chained pinyon-juniper, sagebrush and open hay meadows. In all areas where this species was captured the soil type was loose and sandy-to-sandy-loam. Apparently the preference for this particular soil type is related to the species' burrowing habit which results in a complex tunnel system at the base of rocks or plants (Lechleitner, 1969; Olsen, 1973).

The distribution of Apache pocket mouse is restricted to the states of Utah, Colorado, New Mexico and Arizona. In Colorado it has been

observed along the drainages of the Colorado River in Garfield, Mesa and Montrose counties and in Mesa Verde National Park, Montezuma County (Lechleitner, 1969). It has not previously been reported in Rio Blanco County.

The densities (Table V-9) and relative abundance (Table V-8) of the Apache pocket mouse are not high on Tract C-b suggesting that it is at the northern limit of its geographical distribution. On Grid 1 peak density was recorded in August 1975 (2.8 animals/ha). On the basis of density estimates the Apache pocket mouse represented the fifth-most-abundant, small mammal species on the permanent grids and satellite grids.

Activity was restricted to the warmer months of the year although the animal does not hibernate during winter. Apparently this species is a seed eater and stores seeds collected during warm months for consumption during winter months. Because the Apache pocket mouse is mainly a seed eater, it may avoid direct competition with other, small mammal species on Tract C-b that are generalized and opportunistic feeders.

Reproductive cycles are poorly described for this species although it is likely that several litters are produced during warm months (Lechleitner, 1969).

The remainder of small mammals constituted a small percentage of total captures. It is felt that greater success would result if specific habitats were trapped for the Colorado chipmunk and the bushy-tailed woodrat.

C. Reptiles and Amphibians

1. Relative Abundance and Turnover Rates

Because of their abundance and presumable importance in the biological systems on Tract C-b, lizards were selected for study of population densities. Mark and recapture techniques were employed to provide data for estimating densities. Each lizard was given a unique identification number by toe clipping. Noosing and pit-can captures were the primary means used to obtain individuals for recapture statistics. Sampling areas include animal Grids 1 and 2 and pit-can traps located on each of the grids. Grid lines were walked daily during morning hours when the lizards were at their sunning stations. Lizards are marked and released and their capture location noted. General reconnaissance on the Tract and nearby areas was also employed on a qualitative basis.

During the first year of study on Tract C-b five reptile taxa (including four lizards and one snake) have been observed (Table V-14). A total of 79 lizards were captured on both grids (38 on Grid 1 and 41 on Grid 2) during the June-September, 1975 sampling period (Table V-15). Overall the sagebrush lizard (Sceloporous graciosus) was the most

Table V-14 REPTILES AND AMPHIBIANS OBSERVED ON TRACT C-b, THROUGH SEPTEMBER 1975

Scientific Name	Common Name
AMBYSTOMIDAE	
Ambystoma tigrinum utahensis	Utah tiger salamander
RANIDAE	
Rana pipiens	Leopard frog
IGUANIDAE	
Phrynosoma douglassi	Short-horned lizard
Sceloporus graciosus	Sagebrush lizard
Sceloporus undulatus	Eastern fence lizard
Urosaurus ornatus	Tree lizard
COLUBRIDAE	
Thamnophis elegans	Western terrestrial garter snake

Table V-15 CAPTURE-RECAPTURE HISTORY OF REPTILES ON TRACT C-b

Scientific Name	Common Name	June 1975 No. NC/M*	June 1975 No. R/M*	June 1975 No. C/U*	June 1975 Total	July 1975 No. NC/M	July 1975 No. R/M	July 1975 No. C/U	July 1975 Total	August 1975 No. NC/M	August 1975 No. R/M	August 1975 No. C/U	August 1975 Total	September 1975 No. NC/M	September 1975 No. R/M	September 1975 No. C/U	September 1975 Total	Total Captured	Total Recaptured
GRID I - CHAIN-SITE																			
Phrynosoma douglassi	Short-horned lizard	1			1													1	0
Sceloparus graciosus	Sagebrush lizard	5		2	7	6		5	11	6		7	13			1	1	32	0
Sceloporus undulatus	Eastern fence lizard	1		1	2	1			1			1	1					4	0
Urosaurus ornatus	Tree lizard									1			1					1	0
TOTAL					10				12				15				1	38	0
GRID II - PINYON JUNIPER SITE																			
Sceloporus graciosus	Sagebrush lizard	1		6	7	17	1	9	27		1	5	6			1	1	41	2
TOTAL					7				27				6				1	41	2

*NC/M = New captured/marked
R/M = Recaptured/marked
C/U = Captured/unmarked

abundant lizard and on Grid 2 (pinyon-juniper) it was the only lizard captured or observed. Total numbers observed over four months show that activity at Grid 1 was fairly constant with a slight rise from June to August. At Grid 2 peak activity occurred in July with numbers declining in August. In September activity was very low on both grids.

An insufficient number of recaptures throughout the spring and summer months of 1975 precluded density estimates for lizards on the two permanent grids. Immigration of transient individuals may have accounted for this poor recapture success, especially for the sagebrush lizard. Previous studies (Stevens, 1973) have shown that individual sagebrush lizards which occupy a home range and defend a territory demonstrate considerable tolerance of immigrating individuals. On Tract C-b it appears that large numbers of lizards, captured, marked and released, were immigrants that did not become established nor remain in the study area for longer than one to two weeks. If significant immigration and subsequent emigration of transient sagebrush lizards occurred on Grids 1 and 2, this may explain the low number of recaptures observed there.

Although not available for Grids 1 or 2, previous studies have reported turnover rates for the sagebrush lizard of 35 percent (Stebbins, 1946) and 63.0 percent (Stevens, 1973). Winter mortality appears to be the most significant factor in this population loss (Fitch, 1940; Stebbins, 1944). However, low recaptures in 1975 imply a high turnover rate, which rate includes emigration and mortality.

2. Food Habits

Lizards of the genus Sceloporous generally feed on a wide variety of insects and arachnids (Tolliver and Jennings, 1975). Stomach content analysis of 2,191 sagebrush lizards collected over a 16-year period in Utah yielded 24,000 identifiable insects and terrestrial arthropods. Hymenoptera, Hemiptera and Coleoptera were important food items numerically. The occurrence of large numbers of specific food items indicated that both species may be opportunistic feeders and may exhibit pronounced seasonal variation in their prey selection.

The western garter snake was the only species of snake identified on the Tract. Additional species expected to occur are the western diamondback (Crotalus viridis) and the coach whip snake (Masticophis sp.).

The distribution and species composition of amphibians on and around the Tract were evaluated mainly by reconnaissance of streams and ponds. Observations and hand captures provided information on their relative abundance. The two amphibian species observed on the Tract and in surrounding areas in the first year of study are the leopard frog (Rana pipiens) and the Utah tiger salamander (Ambystoma tigrinum utahensis).

D. Arthropods

Invertebrates are an integral part of most biotic communities. They provide food sources for larger animals, act as scavengers, decomposers,

herbivores and predators and, in many cases, as parasites on other organisms. Figures V-18 and V-19 show the insect-plant/animal interactions with respect to habitat and food.

Data on seasonal abundance and distribution were gathered in several ways. At each, permanent, small-mammal trapping-grid a 7x7 grid of pit-can traps on 15m centers was established. These were used to collect ground-dwelling arthropods such as crickets, spiders and darkling beetles. During each survey pit-cans were checked for arthropods for a two day period. Those collected were placed in vials filled with alcohol and returned to the laboratory for identification. Shrub species present at the two, small-mammal trapping-grids were also sampled for arboreal arthropods. Insects and spiders were collected by sweep net and beating.

Arthropods were collected on Tract C-b from September 1974 through September 1975 to determine the major groups present, their relative abundance, their relationship with the major shrub species and the role of arthropods in the ecosystem of Tract C-b. During this time 2,708 arthropods representing 93 familes were collected. The arthropod community was characterized by an extremely uneven distribution of individuals among the various groups with just nine familes containing over 53 percent of the arthropods collected. These dominant arthropods were the plant bugs, psyllids, aphids, Jerusalem crickets, ground beetles, darkling beetles, ants, wolf spiders and hunting spiders. These arthropods were common during each of the sample periods while the many other taxa appeared much more sporadically, often with only one or two collected during the entire year.

Ground-dwelling arthropods were sampled in two, major vegetation types on Tract C-b (chained pinyon-juniper rangelands and pinyon-juniper woodlands). Although more arthropods were collected by pit-can traps in the pinyon-juniper vegetation than the chained area (523 vs. 288), there does not appear to be any major differences in the arthropod communities for these two areas. Three scavengers/herbivores (Jerusalem crickets, darkling beetles and ants) and three predators (ground beetles, wolf spiders and hunting spiders) were the dominant arthropods in both areas. Other arthropods, e.g., mites, were numerous during some months but were not collected during the majority of sampling periods.

Arthropods were also collected on serviceberry, mountain mahogany and big sagebrush in the same, two, major vegetation types to determine the utiliziation of these shrubs for such requirements as food and cover by different species. The dominant arthropods were the plant bugs, psyllids and aphids. Thrips, leafhoppers and parasitic wasps are also common during some months. The number of taxa and the number of individual arthropods varied from month to month and there were no systematic increases, peaks or decreases in the arthropod community. There do not appear to be any major differences in the kinds of arthropods inhabiting the three species of shrubs sampled. Each shrub species seems to be inhabited throughout the growing season by mostly sucking insects (Hemiptera and Homoptera), predators such as beetles, lacewings and spiders and parasites such as gall-forming wasps and flies.

Figure V-18 HABITAT

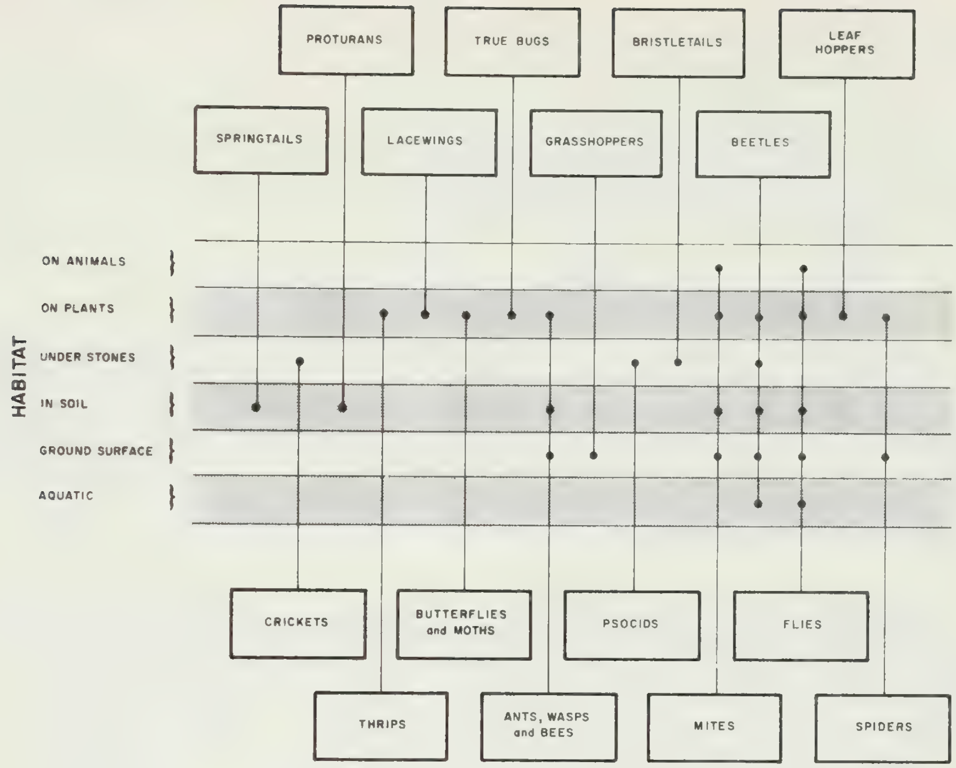


Figure V-19 FOOD

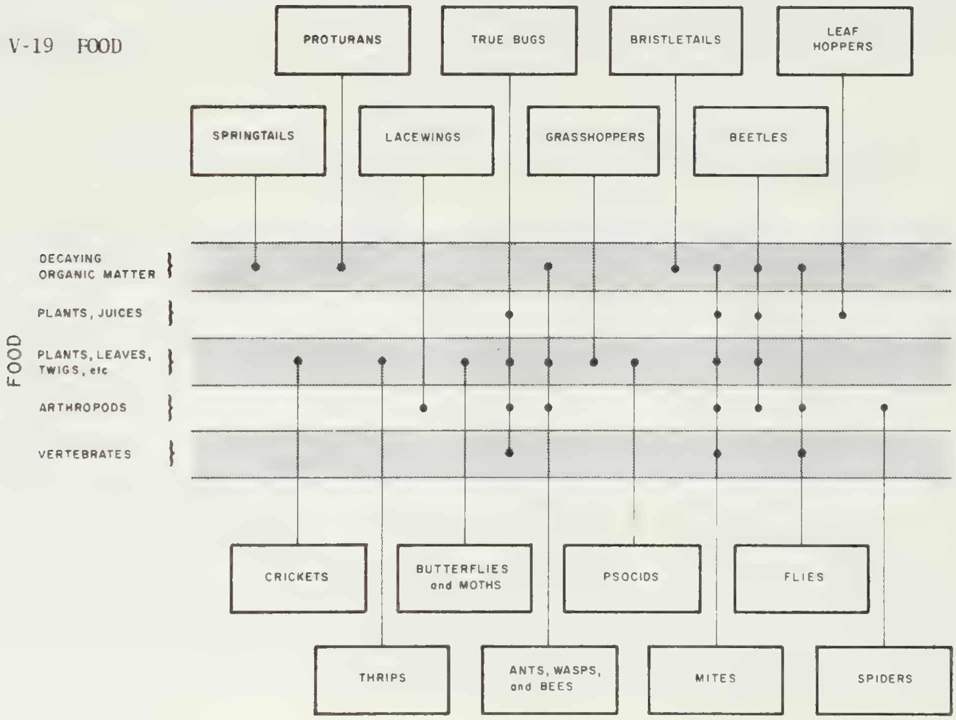


Figure V-19 INSECT-PLANT/ANIMAL INTERACTIONS (FOOD & HABITAT)

E. Avifauna

1. Methodology

Since information on the kinds and abundances of birds utilizing Tract habitats during different seasons is important, a number of survey methods were employed to determine the presence and numbers of songbirds, upland gamebirds, water fowl and raptors.

a. Quantitative Songbird Censuses

Quantitative censuses of songbirds and certain non-songbirds residing in or utilizing major vegetation types on Tract C-b and adjacent areas commenced in early October 1974 and will continue through July 1976. Eight habitats are censused for species composition and abundance according to the schedule specified in Table V-16. Descriptions of sampled habitats are given in Table V-16 and their locations are depicted in Chapter VII on Figure VII-2.

At each of the eight census sites a strip-transect, census procedure is being used to provide data from which bird densities can be calculated. The particular technique employed consists of slowly walking through a strip approximately 800-meters long and 244-meters wide; all individual birds seen and heard within this strip are recorded by species on a standard, field-data form according to their perpendicular distance from the transect at the time of initial observation. Perpendicular distances are recorded according to categories of 7.5 meters, 7.5-15 meters, 15-30.5 meters, 30.5-61 meters and 61-122 meters. The length of each transect was determined by measuring a plot of the route on U.S.G.S., 7.5-minute topographic maps and converting the length to meters.

Strip-transect censuses are conducted during periods of peak activity, generally within 3.5 hours of sunrise and sunset.

Estimates of population density (number per unit area) for species observed on strip transects are determined by one of three methods (Emlen,1971) depending on the conspicuousness of the species to the observer. Since the validity of any of these methods varies for different species, professional judgment, based on experience, is used in selecting the best density estimator.

For species which are associated with distinctive habitat types and occupy a large activity area and are conspicuous, Method "A" usually provides the best density estimate. This method assumes that, because of their conspicuousness and activity, all individuals occupying the strip-transect area are tallied by the censuser. Thus, the method simply involves division of the total number of individuals seen on the transect by the total area of the transect to obtain estimates of number per square kilometer. To determine number per hectare (#/ha), a factor of 0.1 is multiplied by the number of birds observed.

Table V-16 SPECIES NUMBERS, DENSITIES, AND DOMINANCE INDICES FOR AVIAN COMMUNITIES IN EIGHT HABITATS DURING 1974 AND 1975 SAMPLING PERIODS*

Habitat	Sampling Period						
	Oct.	Nov.	Jan.	Mar.	May	July	Sept.
Canyon slope of sparse pinyon-juniper, sage							
Number of species	1	-	5	-	9	-	6
Density (inds./ha)	0.1	-	10.8	-	5.3	-	2.8
Dominance index	100.0	-	90.5	-	38.8	-	70.6
Diversity index (H')	0	-	0.88	-	1.99	-	1.15
Riparian meadow							
Number of species	10	5	4	4	17	11	6
Density (inds./ha)	11.7	13.1	15.7	1.7	12.1	7.4	4.1
Dominance index	63.2	71.3	78.3	90.9	40.6	41.6	55.0
Diversity index (H')	1.54	1.32	1.47	0.66	2.28	2.11	1.62
Valley sagebrush							
Number of species	7	2	3	4	12	11	11
Density (inds./ha)	4.5	0.2	2.3	0.5	9.8	4.6	8.9
Dominance index	73.6	100.0	93.1	66.6	41.9	62.9	71.5
Diversity index (H')	1.33	0.64	0.88	1.27	2.06	1.67	1.51
Pinyon-juniper woodland							
Number of species	4	2	6	2	13	9	16
Density (inds./ha)	1.4	1.2	8.8	0.3	10.6	9.1	20.6
Dominance index	71.5	100.0	67.4	100.0	38.7	77.8	79.6
Diversity index (H')	1.28	0.64	1.52	0.67	2.35	1.84	1.07
Mixed pinyon-juniper/ sage/shrubs							
Number of species	2	-	4	-	11	-	4
Density (inds./ha)	0.3	-	5.4	-	7.3	-	0.6
Dominance index	100.0	-	79.0	-	56.3	-	83.4
Diversity index (H')	0.67	-	1.02	-	1.86	-	1.18
Chained pinyon-juniper rangeland							
Number of species	4	2	0	0	13	7	10
Density (inds./ha)	1.8	0.1	0	0	5.9	6.1	9.6
Dominance index	80.0	100.0	0	0	55.4	70.6	81 [illegible]
Diversity index (H')	1.12	0.69	0	0	2.01	1.41	1.30
Upland sagebrush							
Number of species	0	-	0	-	10	-	6
Density (inds./ha)	0	-	0	-	9.5	-	1.9
Dominance index	0	-	0	-	64.9	-	71.1
Diversity index (H')	0	-	0	-	1.68	-	1.58
Mixed mountain shrubland							
Number of species	3	-	6	-	6	-	4
Density (inds./ha)	2.5	-	13.0	-	3.6	-	0.9
Dominance index	80.7	-	66.1	-	45.0	-	88.9
Diversity index (H')	1.03	-	1.41	-	1.69	-	0.93

*Does not include birds of prey, shorebirds, waterfowl, etc.
- indicates no census was performed during this sampling period.

Method "B" recognizes that most species become less and less conspicuous over distance and therefore have a decreasing probability of being recorded with increasing distance from the transect route. Thus, a coefficient of detectability (C.D.), the proportion of a species' population which is ordinarily detected by an observer, is used to adjust the estimate obtained by Method "A". The coefficient of detectability is determined directly from data on the distribution of detection points perpendicular to the transect route. The transect route bisects the transect area which is divided into a series of strips parallel to the central route. It is assumed that all individuals of a species observed in strips preceeding and including the strip containing the greatest number of birds for that species represent the total number of birds present within those strips. This sum, termed the basal plateau level, is extrapolated to the limits of the entire census band (800 meters by 244 meters) so that the resulting figure represents the projected number of birds for a species within the entire transect. The coefficient of detectability for the species is then determined by dividing the observed number of birds within the transect by the projected number. The C.D. thus represents the efficiency of the census for a particular species. Dividing the density estimates obtained in Method "A" by the coefficient of detectability provides an adjusted, population-density estimate (Emlen,1971).

When the assumption of complete censusing of birds of a species close to the transect route cannot be met, such as in instances of particularly shy or retiring species, Method "C" is employed for density estimation. This method involves multiplication of the estimate obtained in Method "B" by an additional adjustment factor, the basal detectability adjustment. This method adjusts for those species whose conspicuousness diminishes rapidly past some critical distance from the transect route; these birds may not be seen unless they flush nearly underfoot. Emlen (1971) suggested that the basal detectability adjustment should rarely exceed 1.2 for wintering birds and should average about 1.5 for breeding bird populations because of the inactivity of the females and the intermittent singing of the males. Additional field experience will undoubtedly lead to refinements in these adjustment factors.

Once a population density estimate is computed, it is used to determine the percent relative abundance (%RA) for each species. The %RA is defined as follows:

$$\%RA = \frac{\text{density of species A}}{\text{density of all species}} \times 100$$

Since the projected number per hectare takes into account correction factors applied to the observed population count, in the case of strip-transect data, %RA is based on number per hectare rather than actual number observed. In the case of qualitative counts (discussed below), %RA is based on actual numbers of individuals observed.

The Shannon-Weiner calculation (Pielou, 1966) was used to compute indices of species diversity (H') for each habitat type sampled by strip-transect procedures. In these calculations the adjusted number of birds per transect (the product of the number observed and the coefficient of detectability divided by the basal detectability adjustment) was used to adjust for varying conspicuousness of different species. Maximum diversity (H' max) and equitability (J) were also calculated using standard formulae.

b. Qualitative Censuses

Strip-transect techniques are time consuming and are employed to obtain quantitative, baseline data which will form the norm for future comparisons. To be useful for such comparative applications, the strip-transect method is restricted to relatively homogeneous blocks of habitat. Species which prefer mixed or "edge" habitats or species occupying very limited patches of specialized habitat, such as small cattail marshes or the small stands of cottonwoods in Cottonwood Gulch, cannot be properly surveyed by strip-transect techniques. Edge habitats and small, but unusual, habitat patches were inventoried by qualitative censuses to achieve a more complete inventory of bird species which utilize the full range of Tract habitats. Such qualitative observations thus satisfy an inventory role whereas strip-transect data satisfy a baseline establishment role. Because of coverage of a diverse spectrum of habitats, more species are usually encountered in qualitative surveys than quantitative counts.

Qualitative surveys are conducted during each general sampling period. Such surveys consist of walking a route approximately 250 meters long in a given vegetation type and recording all birds encountered, by species and numbers, on a data form. Quantification in these surveys is less rigorous than in standard, strip-transect censuses and because of time constraints they are run during mid-day periods of lower bird activity. Thus, quantitative comparisons between qualitative and strip-transect censuses are usually not reliable. Nonetheless, qualitative surveys serve important functions: they promote more complete assessment of avian diversity in each vegetation type, provide a more complete qualitative rendition of species distributions and develop a more thorough inventory of species inhabiting the Tract vicinity.

c. Upland Gamebirds

Field observations made during conduct of strip-transect, qualitative, waterfowl and raptor censuses have demonstrated the regular occurrence of only one upland gamebird, the mourning dove, on or close to the Tract. Distribution and abundance of this dove are determined by strip-transect and qualitative survey methods. Sage grouse occasionally are in the study area. The infrequency of their appearances precludes any meaningful census of their numbers.

d. Waterfowl

Waterfowl utilization of the Walter Oldland Ranch Pond (NE¼ NE¼, Sec. 5, T3S, R96W) and the P-L Ranch Pond (SW¼, SE¼, Sec. 26, T2S, R97W), the two ponds close to Tract C-b, was determined bimonthly by recording the number of individuals present on the ponds by species. Each of these ponds was visited between three and nine times each sampling period. Utilization in bird-use-days was calculated according to methods of Banfield (1947). For convenience geese, ducks and shorebirds are considered herein as "waterfowl."

e. Raptors

Raptorial birds include the vultures, hawks, eagles, falcons and owls. The common raven is included in this category owing to its similar ecological role (Craighead and Craighead,1969). During all field periods observed raptors were recorded as to location, species and age class based on criteria developed by Bent (1961), Peterson (1947, 1961) and Brown and Amadon (1968). Locations of all raptor nests encountered were mapped. During the nesting season a search was made of all Tract habitats considered to provide suitable raptor nest sites. Also at this time nests were revisited and checked for occupancy; the species occupying each active nest was determined.

During November 1974 and May 1975 a standardized, road transect was traversed at night to assess owl activity. These surveys commenced within two hours after sunset. The road transect consisted of 30 stops, each permanently marked with a stake and flagging tape, located approximately 1.13 km apart. At each stop, the censuser left the vehicle, walked approximately 15 meters away and recorded on a data sheet, by species, the number of owls heard or observed during a 5-minute period.

During March, May and October 1975 pellets and casts were collected from nesting, roosting and feeding sites used by birds of prey. These were labelled as to raptor species and collection location. Pellet dissections were performed to determine raptor use of prey species. Results of pellet analyses are discussed in Chapter VII.

2. Data Quality

a. Quality Assurance

A number of activities are routinely performed to assure that field data are obtained using standardized, repeatable methodologies, that data records are complete and that data analyses are accomplished correctly and accurately. These activities constitute a project-specific, quality-assurance program and include:

- Marking all strip transects and road transects with flagging to permit repeatability of field survey routes;

- Use of a rangefinder during initial, strip-transect censuses to calibrate distance-estimation skills of the observer with actual distance measurements;

- Field audits of the project ornithologist by another party, using audit procedures specified in Ecology Consultants, Inc.'s Quality Assurance Manual. These audits determine whether conduct of field work and the field schedule are in conformance with procedures specified for work on Tract C-b, and specify corrective action if variances are ascertained;

- Use of standard, field-data forms to assure that all necessary information is recorded at the time of field work;

- Checks of field-data forms by an independent party to assure that forms are complete and legible;

- Duplication of all data sheets to minimize chances for irreparable data loss;

- Editing of computerized data lists to assure correctness of data transfer from field-data forms to computer tape;

- Computer analysis of strip-transect and species-diversity data to eliminate chances of human error; production of data tables via computer-activated typewriter to eliminate errors in summary data tabulation; and

- Analysis of a known-value data set prior to computer analysis of strip-transect data to check possible computer malfunction.

b. Efficacy of General Data

Birds are highly mobile and during the non-breeding season they often exhibit extreme nonuniformity in their distribution-patterns and density estimation becomes risky. Thus, it is often necessary to qualify the meaning of bird-density values derived from even the best, field census procedures. In the data interpretation section, occasional qualifications are made as deemed necessary and a brief generic-level treatment of potential data limitations is presented.

(i) Winter Mixed-Flock Behavior

Commencing in late fall and continuing until early spring, many permanent and winter resident species of the Piceance Basin congregate in mixed-species flocks. These flocks are usually nonstationary; the individuals comprising them exploit food resources in a very localized area for a few hours, or in the case of a rich food source, longer periods, before moving en masse to another feeding or roosting location. The resultant pattern of distribution accounts for vast areas of Tract C-b remaining devoid of birds at a particular time while a number of small areas temporarily support dense congregations. Field data obtained during the winter reflect the inconsistent pattern of habitat utilization caused by this dynamic behavior of winter flocks. Few or no birds will be tallied along some 0.8 km transects while other transects,

which fortuitously include a mobile,winter flock within the censused strip, will tally a large number of individuals. Moreover, reduced visual and audible conspicuousness of individual birds that do not flock decreases their potential of being observed. Consequently, individual conspicuousness and flock conspicuousness will strongly influence the species that are recorded and their population numbers. Additionally, the generalized nature of habitat utilization exhibited by wintering birds and avoidance of windswept habitats, such as chained pinyon-juniper rangelands and upland sage communities, requires the qualification of the interpretation of population densities in a given habitat.

(ii) Migratory Behavior

Generally during migration species do not exhibit the well-defined habitat preferences and attachment to specific locations shown by them during the breeding season and investigators must recognize certain basic characteristics. During migration many nocturnally migrating species stop their directional movement each morning to feed and rest in loosely organized flocks, thus bird distribution can be highly clumped or aggregated similar to patterns exhibited by mixed winter flocks. As a consequence, a series of bird density estimations determined over a number of successive migration periods must not be interpreted as providing data which are directly comparable for long-term trends.

Species composition within a region during migration is dynamic and an assemblage of migrant species can quickly be replaced by a wave dominated by entirely different species. Densities can also vary markedly from day to day during migration as bird numbers increase in an area when poor weather stalls advance and decline abruptly when favorable weather returns. This dependency of migratory dynamics on weather conditions has been well documented (Curtis,1969, 1970; Hassler et al., 1963). The exact path,which a flock of birds takes,may also be determined by the extent to which the migrating flock is displaced by winds (Graber,1968).

A consequence of avian population dynamics during migration is that migrant species' density-values are of limited use. Hence, census results by any method from periods of autumn and spring migration are not appropriately used as baseline data, but are, nonetheless, important to satisfying the requirement that an inventory be made of species utilizing Tract C-b habitats during migration.

(iii) Wide-Ranging Species

Most birds of prey range over wide areas during hunting activities. A single golden eagle, for instance, may traverse as much as 20 mi^2 in the course of daily hunting. Such movements over large areas preclude effective estimation of population densities by any census method that is restricted to specific vegetative communities. Because strip-transect data on birds of prey are not amenable to density estimations, tallies of buteos, accipiters, eagles and falcons made during transect censuses were excluded from calculations of bird densities at each of the transects.

(iv) Aerially-Feeding Species

Nighthawks, swifts and swallows feed by capturing insects on the wing, so most tallies of these species involve observations of birds in flight. Because these species sometimes concentrate in areas of insect congregations, censuses of transects supporting such temporary concentrations tend to overestimate densities of these species. Overestimates of this nature result from all census techniques which tally numbers of swallow-like birds.

Based on conclusions from discussions presented above, density data derived from migration and winter periods must be carefully qualified. Conversely, because breeding birds exhibit tenacity to territories and are dispersed throughout their preferred habitat, quantitative data on certain permanent and summer-resident species' densities obtained during the nesting period are usually reliable indicators of abundances, given qualifications indicated below which relate to intrinsic limitations of the specific, strip-transect methodology being employed.

(v) Habitat Heterogeneity

Censuses aimed at establishing avian densities assume that the habitat being sampled is homogeneous and characteristic of the vegetative community of interest. The strip-transect methodology employed in the Tract vicinity requires a relatively large, sampling area (approximately 2,625 feet x 800 feet); careful placement of transects minimizes the inclusion of multiple habitats within a single transect. Nonetheless, patches of dissimilar habitats do occur within most transects. These patches sometimes attract species which are not characteristic of the specific habitat being censused and occasionally such species are tallied during the census. Strip-transects in both Collins Gulch and West Fork Stewart Gulch pose clear problems in this regard.

(vi) Overestimations from Single Sightings in Innermost Transect Strip

The extrapolation of basal, plateau-level values to the entire transect width tends to produce overestimates of density when a species is observed only once or twice and sightings are confined to the strip closest to the transect route. For species tallied a number of times on a transect, this problem does not arise. To reduce the magnitude of such overestimations, sightings in the two, innermost strips were combined for the purpose of calculating density.

(vii) Census Replication

Because a single census was made of each transect during each sampling period, statistical treatment to determine within-season variability is not possible. During May, 1976, each transect will be censused in triplicate to permit statistical assessment of data variability during the season when density estimates are most valuable.

3. Results

a. Data Summary

Species observed on and close to the Tract during seven periods of field inventory, spanning the interval from early-October 1974 through mid-September 1975, are listed in Table V-18; numerically important species are discussed in the section on Interpretive Summary. A summary of the winter and breeding avifaunas in four principal habitats in the Tract C-b study area is the subject of Table V-17 and community density, bird species' diversity and dominance indices for each of the sampled habitats are compiled for each census period in Table V-16.

b. Interpretive Summary

During seven census periods, 125 species have been observed within the study area (Table V-18). Studies performed in other parts of the Piceance Basin have established that an additional 32 species are inhabiting vegetative communities characteristic of the general Tract C-b region. Thus, a minimum of 157 species can be expected to occur in the study area. Many unlisted species of minor transient importance undoubtedly appear in the Tract vicinity from time to time during migration, so it is expected that the inventory of species utilizing habitats in the area will continue to expand. Certain of the species still anticipated to be sighted will be waterfowl having minor recreational importance. Also, one endangered species, the peregrine falcon, is expected to occasionally hunt over and migrate through the Tract vicinity and will certainly be observed during some future field activities.

Thirty-seven species were noted in Tract habitats during midwinter; a minimum of 84 of the species tabulated in Table V-18 is expected to nest in the general Tract vicinity.

(i) Songbirds

The October 1974 census period occurred near the mid-point of the fall migration for many songbirds. Nonetheless, many species of summer residents such as swallows, rock wren, western flycatcher, mountain bluebird, mourning dove and red-winged blackbird were still present. Evidences of seasonal change were evident as species which breed at higher elevations in the Colorado mountains, such as Clark's nutcracker, Townsend's solitaire and Steller's jay, had arrived on the Tract.

The only habitat supporting a significant bird density during fall was the agricultural meadow vegetative-type along Piceance and Willow Creeks. Along Piceance Creek almost 12 birds/ha were recorded in early October (Table V-16). Three species, the red-winged blackbird, white-crowned sparrow and song sparrow accounted for 90 percent of the total bird density at this location. By late November, the blackbirds and white-crowned sparrows were much less numerous; both species were entirely

Table V-17 CHARACTERISTICS OF WINTERING AND BREEDING AVIFAUNA IN FOUR PRINCIPAL HABITATS IN TRACT C-b STUDY AREA

Species	Winter % Relative Density	Summer % Relative Density
PINYON-JUNIPER HABITAT		
Pinyon jay	11.6	
Mountain chickadee	27.9	6.7
Red-breasted nuthatch	39.5	
Chipping sparrow		43.8
Blue-gray gnatcatcher		9.0
House finch		9.0
Solitary vireo		9.0
Black-throated gray warbler		9.0
Number of species recorded	6	9
Total density (no./ha)	8.8	9.1
Dominance index	67.4	52.8
% of breeding species which are migratory	-	77.8
CHAINED PINYON-JUNIPER HABITAT		
House wren		53.8
Vesper sparrow		13.4
Brewer's sparrow		16.8
Number of species recorded	0	7
Total density (no./ha)	0	6.1
Dominance index	0	70.6
% of breeding species which are migratory	-	85.7
VALLEY SAGEBRUSH HABITAT		
American robin	54.5	
Tree sparrow	38.6	
Glue-gray gnatcatcher		18.0
Yellow-rumped warbler		9.0
Green-tailed towhee		9.0
Brewer's sparrow		44.9
Number of species recorded	3	11
Total density (no./ha)	2.3	4.6
Dominance index	93.1	62.9
% of breeding species which are migratory	-	90.1

Table V-17 (CONTINUED)

Species	Winter % Relative Density	Summer % Relative Density
	RIPARIAN MEADOW HABITAT	
Horned lark	60.1	
American robin	13.7	
Tree sparrow	18.3	
Red-winged blackbird		19.4
Song sparrow	7.8	22.2
Chipping sparrow		16.7
Say's phoebe		11.1
Yellowthroat		11.1
Number of species recorded	4	11
Total density (no./ha)	15.7	7.4
Dominance index	78.4	41.6
% of breeding species which are migratory	-	90.1

Table V-18 SPECIES OF BIRDS OBSERVED ON TRACT C-b DURING THE FIRST YEAR'S FIELD INVESTIGATIONS

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
ANSERIFORMES					
ANATIDAE					
Anas platyrhynchos	Mallard	x	x	x	x
Anas strepera	Gadwall	x	x		
Anas acuta	Pintail	x		x	
Anas crecca	Green-winged teal	x	x	x	x
Anas discors	Blue-winged teal	x			x
Anas americana	American wigeon	x	x	x	
Anas clypeata	Northern shoveler	x			
Anas cyanoptera	Cinnamon teal			x	x
Aix sponsa	Wood duck			x	
Bucephala clangula	Common goldeneye		x	x	
Bucephala islandica	Barrow's goldeneye		x		
Bucephala albeola	Bufflehead		x		
Mergus serrator	Red-breasted merganser		x		
FALCONIFORMES					
CATHARTIDAE					
Cathartes aura	Turkey vulture	x		x	x

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
FALCONIFORMES (Cont.)					
ACCIPITRIDAE					
Accipiter gentilis	Goshawk				x
Accipiter cooperii	Cooper's hawk	x			x
Circus cyaneus	Marsh hawk	x			
Buteo lagopus	Rough-legged hawk	x	x	x	
Buteo jamaicensis	Red-tailed hawk	x		x	x
Aquila chrysaetos	Golden eagle	x	x	x	x
Haliaeetus leucocephalus	Bald eagle			x	
FALCONIDAE					
Falco mexicanus	Prairie falcon	x	x		
Falco sparverius	American kestrel	x	x	x	x
GALLIFORMES					
TETRAONIDAE					
Centrocercus urophasianus	Sage grouse	x			
GRUIFORMES					
GRUIDAE					
Grus canadensis	Sandhill crane	x			
RALLIDAE					
Fulica americana	American coot	x			x

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation			
		Fall	Winter	Spring	Summer
CHARADRIFORMES					
CHARADRIIDAE					
Charadrius vociferus	Killdeer			x	
SCOLOPACIDAE					
Capella gallinago	Common snipe	x	x	x	x
Actitis macularia	Spotted sandpiper			x	x
Tringa solitaria	Solitary sandpiper	x			x
Tringa flavipes	Lesser yellowlegs	x			
RECURVIROSTRIDAE					
Recurvirostra americana	American avocet				x
PHALAROPODIDAE					
Steganopus tricolor	Wilson's phalarope				x
COLUMBIFORMES					
COLUMBIDAE					
Zenaidura macroura	Mourning dove	x		x	x
STRIGIFORMES					
TYTONIDAE					
Tyto alba	Barn owl	x			

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
STRIGIFORMES (Cont.)					
STRIGIDAE					
Otus asio	Screech owl	x			x
Bubo virginianus	Great horned owl	x	x	x	x
Asio otus	Long-eared owl	x			
Nyctea scandiaca	Snowy owl		x		
Aegolius acadicus	Saw-whet owl				x
CAPRIMULGIFORMES					
CAPRIMULGIDAE					
Phalaenoptilus nuttalli	Poor-will				x
Chordeiles minor	Common nighthawk	x			x
APODIFORMES					
APODIDAE					
Aeronautes saxatalis	White-throated swift				x
TROCHILIDAE					
Selasphorus platycercus	Broad-tailed hummingbird				x

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation			
		Fall	Winter	Spring	Summer
CORACIIFORMES					
ALCEDINIDAE					
Megaceryle alcyon	Belted kingfisher	x		x	
PICIFORMES					
PICIDAE					
Colaptes auratus	Common flicker	x	x	x	x
Sphyrapicus thyroideus	Williamson's sapsucker				x
Dendrocopos villosus	Hairy woodpecker	x			
Dendrocopos pubescens	Downy woodpecker	x	x		
PASSERIFORMES					
TYRANNIDAE					
Myiarchus cinerascens	Ash-throated flycatcher				x
Sayornis saya	Say's phoebe	x		x	x
Epidonax wrightii	Gray flycatcher				x
Epidonax difficilis	Western flycatcher	x			
Contopus sordidulus	Western wood pewee			x	x
Nuttallornis borealis	Olive-sided flycatcher				x

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
PASSERIFORMES (Cont.)					
ALAUDIDAE					
<u>Alauda arvensis</u>	Horned lark	x	x		x
HIRUNDINIDAE					
<u>Hirundo rustica</u>	Barn swallow	x			x
<u>Petrochelidon pyrrhonota</u>	Cliff swallow	x			x
<u>Tachycineta thalassina</u>	Violet-green swallow	x			x
<u>Iridoprocne bicolor</u>	Tree swallow				x
<u>Stelgidopteryx ruficollis</u>	Rough-winged swallow				x
CORVIDAE					
<u>Cyanocitta stelleri</u>	Steller's jay	x	x		
<u>Aphelocoma coerulescens</u>	Scrub jay	x		x	x
<u>Gymnorhinus cyanocephalus</u>	Pinyon jay	x	x	x	
<u>Pica pica</u>	Black-billed magpie	x	x	x	x
<u>Nucifraga columbiana</u>	Clark's nutcracker	x	x	x	x
<u>Corvus corax</u>	Common raven	x	x	x	x
<u>Corvus brachyrhynchos</u>	Common crow	x			

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
PASSERIFORMES (Cont.)					
PARIDAE					
Parus atricapillus	Black-capped chickadee	x	x		
Parus gambeli	Mountain chickadee	x	x	x	x
Parus inornatus	Plain titmouse			x	
SITTIDAE					
Sitta carolinensis	White-breasted nuthatch	x	x		
Sitta canadensis	Red-breasted nuthatch	x	x		
TROGLODYTIDAE					
Troglodytes aedon	House wren	x			x
Salpinctes obsoletus	Rockwren	x			x
Catherpes mexicanus	Canyon wren	x		x	
MIMIDAE					
Sporeoscoptes montanus	Sage thrasher	x			
TURDIDAE					
Turdus migratorius	Robin	x	x	x	x
Myadestes townsendii	Townsend's solitaire	x	x		x
Hylocichla guttata	Hermit thrush				x
Sialia currucoides	Mountain bluebird	x		x	x

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
PASSERIFORMES (Cont.)					
SYLVIIDAE					
Polioptila caerulea	Blue-gray gnatcatcher	x			x
Regulus calendula	Ruby-crowned kinglet	x			
LANIIDAE					
Lanius excubitor	Northern shrike	x	x	x	
Lanius ludovicianus	Loggerhead shrike			x	
STURNIDAE					
Sturnus vulgaris	Starling	x		x	
VIREONIDAE					
Vireo solitarius	Solitary vireo	x			x
Vireo olivaceus	Red-eyed vireo				x
Vireo gilvus	Warbling vireo				x
PARULIDAE					
Vermivora ruficapilla	Orange-crowned warbler				x
Vermivora virginiae	Virginia's warbler				x
Dendroica petechia	Yellow warbler				x
Dendroica coronata	Yellow-rumped warbler	x			x
Dendroica nigrescens	Black-throated warbler	x			x

Table V-18 (CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation Fall	 Winter	 Spring	 Summer
PASSERIFORMES (Cont.)					
PARULIDAE (Cont.)					
Dendroica townsendi	Townsend's warbler	x			
Geothlypis trichas	Common yellowthroat				x
Oporornis tolmiei	MacGillvray's warbler				x
Wilsonia pusilla	Wilson's warbler				x
ICTERIDAE					
Dolichonyx oryzivorus	Bobolink				x
Sturnella neglecta	Western meadowlark	x		x	x
Xanthocephalus xanthocephalus	Yellow-headed blackbird	x			
Agelaius phoeniceus	Red-winged blackbird	x		x	x
Euphagus cyanocephalus	Brewer's blackbird	x			x
Molothrus ater	Brown-headed cowbird				x
THRAUPIDAE					
Piranga ludoviciana	Western tanager				x
FRINGILLIDAE					
Pheucticus melanocephalus	Black-headed grosbeak				x
Carpodacus mexicanus	House finch	x			x
Leucosticte tephrocotis	Gray-crowned rosyfinch		x		
Leucosticte atrata	Black rosy finch		x		

Table V-18(CONTINUED)

ORDER FAMILY Species	Common Name	Season of Observation			
		Fall	Winter	Spring	Summer
PASSERIFORMES (Cont.)					
FRINGILLIDAE (Cont.)					
Leucosticte austcalis	Brown-capped rosy finch		x		
Spinus pinus	Pine siskin	x			x
Spinus tristis	American goldfinch	x			
Chlorura chlorura	Green-tailed towhee	x			x
Pipilo erythrophthalmus	Rufous-sided towhee	x			x
Passerculus sandwichensis	Savannah sparrow	x			
Calamospiza melanocorys	Lark bunting				x
Pooecetes gramineus	Vesper sparrow	x			x
Amphispiza belli	Sage sparrow				x
Junco hyemalo	Dark-eyed junco		x	x	
Junco caniceps	Gray-headed junco	x	x	x	x
Spizella arborea	Tree sparrow	x	x	x	
Spizella passerina	Chipping sparrow	x			x
Spizella breweri	Brewer's sparrow	x			x
Zonotrichia leucophrys	White-crowned swallow	x			x
Melospiza melodia	Song sparrow	x	x	x	x

gone by early winter. The song sparrow is a permanent resident and was surely present in this habitat throughout the year, despite not being encountered on the March and September quantitative censuses. The raparian meadow habitat also attained the highest diversity-index of all transects censused in October. At the other extreme, no birds were present in the upland sagebrush habitat in October and only one individual was seen along transect 1 in the October census. Strong winds at the time of sampling made these habitats unattractive to most species.

Only six other species (Townsend's solitaire, yellow-rumped warbler, mountain bluebird, gray-headed junco, mountain chickadee and ruby-crowned kinglet) were encountered frequently during fall censuses. The solitaire was present in four of the transects and the bluebird was present in three transects. These plus the yellow-rumped warbler dominated the avifauna in the valley sage and in combination with the gray-headed junco were the principal species in the chained pinyon-juniper-rangeland habitat. Mountain chickadees and ruby-crowned kinglets were most important in mixed mountain shrublands.

By late November most summer residents and migratory species had left the Tract region and more winter residents had appeared. Many of the wintering species fed and rested in loosely organized flocks which appeared to move over large portions of the Tract and to feed in a variety of different habitats. As in October, only the riparian meadow supported a dense assemblage of birds (13.1 individuals/ha vs. 1.2 individuals/ha for the second densest habitat); it also achieved a reasonably high diversity of species (Table V-16). At the time of censusing, large flocks of robins and starlings were foraging in the meadow bordering Piceance Creek. Song sparrows were the only other birds present in substantial numbers. Although a few, white-crowned sparrows and a single, red-winged blackbird were still present, the bird species' composition of the riparian meadow had changed markedly between early October and late November. This was also the case for the other three transects sampled during November.

Virtually all summer residents and migrant species observed during the early and late fall inventory periods had departed the Tract by January. Individuals of certain migratory species such as the horned lark and American robin, which were present in January, were most likely birds that moved into the area subsequent to nesting in more northerly localities. Others probably summered at nearby higher elevations and descended into lower parts of the Piceance Basin for the winter. Table V-17 summarizes the principal, wintering, songbird species for four major habitats in the study area. The seven species listed as achieving high relative densities are expected to be present in the Tract vicinity in most or all winters. In addition to these species large numbers of rosy finches were feeding on seeds of annual plants in Collins Gulch,and the mixed mountain shrubland community at transect 8 was inhabited by many mountain chickadees and dark-eyed and gray-headed juncos; all are flocking species and expected to recur in the Tract area each winter.

In January the riparian meadow habitat again supported the highest bird density of all the transects but its density was almost equalled by bird numbers in the mixed mountain shrubland (Table V-16). Because large flocks of horned larks and American robins were present in meadows bordering Piceance Creek, species equitability was relatively low in this habitat and the pinyon-juniper-woodland transect attained the highest species diversity-index.

Two habitat types, the chained pinyon-juniper rangeland and the upland sage, are subjected to severe conditions by winter winds. Birds were not present on transects censused in either of these habitats during January. Moreover, no birds were tallied on the chained pinyon-juniper transect during March and during November this transect sustained the lowest density of the four transects censused in that month. Based on these observations combined with few sightings on qualitative counts made in this habitat type during winter, it is probable that the extensive chaining which occurred during the 1960's has markedly affected winter distribution of birds on Tract C-b.

In mid-March most songbirds on the Tract were still in mixed flocks. Flocks of wintering species were not encountered on the four, 800-feet-x-244-feet transects censused at that time,and low densities were recorded at all transects. Again, the riparian meadow habitat achieved the highest density-value (Table V-16), but it was much lower than for any other census period. Qualitative censuses indicated that most winter residents were still present on the Tract. Large groups of dark-eyed and gray-headed juncos were encountered and other wintering birds (Clark's nutcracker, Townsend's solitaire, northern shrike and tree sparrow) had not yet departed. However, March was a period of change in species composition as the vanguard of migrant and summer resident species was arriving. More than 500, red-winged blackbirds were observed in agricultural meadows near Tract C-b and migrating mountain bluebirds were conspicuous in open vegetative communities which contained scattered trees.

Qualitative observations during mid-April demonstrated advancement in compositional changes. Killdeer, Say's phoebes, western wood pewees, mountain bluebirds and red-winged blackbirds were present in the study area while most winter residents were absent. Males of some species had begun to defend territories by this time.

More species were recorded in late May censuses than in any other sampling period. At this time territorial activities made most species relatively conspicuous and virtually all summer residents were observed. In addition certain, late, spring migrants were still in the area. The mixture of migrants and breeding species accounted for species' diversity-values which were higher in each of the sampled habitats than values recorded during any of the other six census periods (Table V-16).

For the fifth,consecutive,census period the riparian meadow transect exhibited the highest density. Average density per transect was greater than for any of the other,six,census periods. Pinyon-juniper woodland attained the greatest calculated species diversity, with the riparian meadow having the second richest diversity despite supporting more total species than any other transect.

Considering all transects, 14 species were tallied which achieved at least ten-percent, relative abundance within their preferred habitats. All were species that remained to nest on the Tract. Two species (broad-tailed hummingbird and green-tailed towhee) each comprised greater than ten-percent, relative density in four of the eight transects. The towhee was numerically important in four habitats possessing a well-developed shrub stratum. Vesper and Brewer's sparrows were also strongly associated with shrubby habitats, while chipping sparrows were the most abundant species in pinyon-juniper woodlands.

Between late spring and mid-summer, 84 species were recorded on and near the Tract (Table V-18). Comparison of relative density-values for principal species in the four, major, Tract habitats for January and July censuses demonstrates clearly that the Tract's avifauna changes markedly from winter to summer. During winter, habitats in the vicinity tend to support fewer species. Most breeding species leave the Piceance Creek Basin to winter at locations farther south. In woodland and shrub habitats, 78 to 90 percent of the breeding, songbird species did not remain through the winter. In meadow habitat along Piceance Creek 90 percent of nesting songbird species were migratory. Wiens (1975) indicated that a high, migratory propensity is typical of shrub-steppe avifaunas and he believed that the available supply of winter food (principally seeds) is lower in shrub communities than in grassland communities, thus accounting for a fall exodus of shrub habitats.

Except for the chained pinyon-juniper habitat, each principal habitat contained four or five nesting species which achieved a relative abundance of about ten percent or greater. The data demonstrate that chaining dramatically altered the species' composition from that of the original woodland. Of 26 species present in the two habitats during late May, only three (broad-tailed hummingbird, house wren and chipping sparrow) occurred in both communities, all in low relative densities except for the hummingbird in the chained pinyon-juniper rangeland. Table V-16 which tallies community characteristics of the chained and unchained pinyon-juniper habitat for seven, sampling periods, shows further disparities between these habitats. As indicated earlier, absence or sporadic occurrence of birds in the chained areas during winter probably is a consequence of strong winds which sweep the open areas, coupled with drifting snow, poor food availability and poor cover.

During July total density was greatest in the pinyon-juniper woodland transect; the riparian meadow supported the second highest density and the highest, calculated, species' diversity. This was the first time in six census periods that the agricultural meadows along Piceance Creek did not have the highest density of birds. As in other non-winter censuses, red-winged blackbirds and song sparrows were the most important species, in terms of density, in these meadows. Table V-17 lists species which were dominant in three other Tract habitats during the nesting period.

The dominance index, which summarizes relative densities for the two species achieving greatest density, indicates that most avian communities on the Tract are dominated by two species. The breeding assemblages of birds in Tract habitats are simple in structure. The summary values in Tables V-16 and V-17 also demonstrate substantial seasonal variations in density for most habitats. Certain reasons for these variations were described in the section on efficacy of general data, but, in addition, it is clear that the Tract supports fewer birds during some seasons than others. It is probable that such density variations are characteristic of the surveyed habitats. Based on recent literature on seasonal and annual variations in bird densities, it is expected that marked, year-to-year variations in breeding densities will occur. However, the species' composition of the breeding avifaunas will remain relatively stable from year-to-year in the absence of major disturbances.

Based on average densities of birds over seven census periods the riparian meadow habitat supported the greatest number of birds (mean density = 9.4 birds/ha); the pinyon-juniper woodland averaged the second highest density (7.5 birds/ha), while the chained pinyon-juniper habitat ranked seventh with 3.3 birds/ha.

(ii) Upland Gamebirds

Only two species of upland gamebirds, the mourning dove and sage grouse, have been observed within the study area. Based on droppings, which have been noted in sagebrush vegetation immediately south of the Tract, it is clear that a few sage grouse inhabit the vicinity. Sage grouse sign, in the form of tracks or droppings, has been seen only once on Tract C-b proper. Sagebrush communities on the Tract are not sufficiently large to support a sage-grouse population. Hence, discovery of leks or nesting concentrations in the study area are not anticipated. Blue-grouse habitat appears restricted to points southeast and south of the Tract. No blue grouse have been seen to date in the Tract vicinity.

During the 1975 nesting period mourning doves were recorded in every habitat on the Tract and were observed on four of the eight strip-transect censuses. Fall migration of doves usually commences near the end of August. Prior to migration, large flocks usually congregate along streams and in valley sagebrush and open pinyon-juniper communities reasonably close to water. Mourning doves begin reappearing in the Tract vicinity in early April. During 1975 they congregated along Piceance Creek after their initial arrival.

(iii) Waterfowl

Thirteen duck species and nine species of shorebirds or cranes have been observed in the Tract C-b study area. During the fall waterfowl in the impoundments along Piceance Creek included mallards, green-winged teal and blue-winged teal. These birds were subject to moderate hunting pressure by resident, waterfowl hunters. Mallards and green-winged teal comprised the largest proportion of waterfowl in November. During winter mallards and green-winged teal were the numerically dominant

species totalling 70 percent of all waterfowl present. The American wigeon, common goldeneye and bufflehead contributed an additional 24 percent to relative abundance. The gadwall, Barrow's goldeneye and red-breasted merganser contributed the remaining six percent.

Late-winter, waterfowl counts conducted in March 1975 indicated high usage of the area by six waterfowl species. The mallard and green-winged teal were most numerous. Pintails, American wigeons, cinnamon teal and common goldeneye were also present. Several species of waterfowl and shorebirds considered unusual in the region were encountered near the Tract, i.e., the Barrow's goldeneye, red-breasted merganser and Wilson's snipe. A single, male, Barrow's goldeneye was identified in the P-L Ranch pond during January 1975. The only other known documented record of this rare, winter migrant in this region was by Good (1956), who saw a male goldeneye on the Green River northeast of Escalante Crossing. Four individuals, one male and three females, of the red-breasted merganser were observed on the P-L Ranch pond in late January 1975. Davis (1969) classifies this species as an uncommon, winter resident on open rivers. This species has been reported as a frequent visitor to the Green River in northeastern Utah and northwestern Colorado during migration in early May and late September. The Wilson's snipe has been observed repeatedly in the Tract vicinity and undoubtedly nests in the Piceance Creek Basin. Previously, its known nesting range on the Western Slope included Routt, Moffat and Gunnison counties.

The P-L ranch pond was the only site of significant use by nesting waterfowl from May through July 1975. Nine species were recorded at the impoundments near Piceance Creek. Mallards, green-winged teal and cinnamon teal were the dominant, breeding species.

One species, the greater sandhill crane, deserves special mention. The population of greater sandhill cranes that nests within Colorado has been recognized as "endangered" by the Colorado Divison of Wildlife. This designation does not apply to populations stopping temporarily within Colorado during migration periods. During April 1975, a flock of cranes was observed foraging and displaying on a sagebrush-covered mesa in a northern area of the Piceance Basin. No cranes were observed near Tract C-b during spring, but in early October, a flock of approximately 20 cranes was observed feeding in the Tract vicinity and at a number of points along Piceance Creek. Also during October, it was reported that cranes reappeared on the mesa near Tract C-a.

Lack of crane observations in the Tract C-b region during the nesting period, information accumulated by extensive surveys and interviews performed for Rio Blanco Oil Shale Project (ECI, 1975) suggest that cranes, which are sighted in the Piceance Basin during spring and fall, are probably migrants using portions of the basin for foraging and staging during the migratory period. Whether these birds migrate on to locales outside Colorado (Drewien and Bizeau,1974) or to nesting areas along the Yampa Valley (ECI,1973; Martin, Baldwin and Reed,1974) or in Routt County (Blake,1974; Bailey and Niedrach,1965) remains unknown. If migrant cranes stopping along Piceance Creek ultimately nest within Colorado, they are classified as endangered.

(iv) Raptors

Table V-19 indicates the percent relative abundance of the 429 birds of prey and ravens observed on the Tract C-b study area between October 1974 and September 1975. Ten diurnal-hawk, vulture and eagle species, one diurnal-owl species, five nocturnal-owl species and the raven have been observed through September. Nests of nine of the 17 species have been located by ECI's ornithologists in Piceance Basin habitats. At least four other species are expected to nest in the region. The three winter residents breed farther north.

Diurnal raptorial birds observed during the October-November 1974 sampling periods included the red-tailed hawk, rough-legged hawk, golden eagle, marsh hawk and American kestrel. The barn owl, screech owl, great horned owl and long eared owl were nocturnal species observed during fall. The most abundant of the fall raptors were the golden eagle and marsh hawk.

During winter the rough-legged hawk, golden eagle, American kestrel, great horned owl and snowy owl were identified. The rough-legged hawk was by far the most frequently observed species, constituting about 75 percent of all winter sightings. Rough-legged hawks began appearing in the area during late November and were abundant in the Piceance Creek Basin by mid-January. In March 1975, nine species of raptors were observed on the Tract. The most frequently observed species (about 62 percent) during the late winter was the common raven. The red-tailed hawk was also frequently observed. The rough-legged hawk was observed on only two occasions during March and not at all during April. This species nests in the arctic, and its northward migration had commenced prior to mid-March. Golden eagles were seen on 12 occasions in April. One pair of golden eagles was observed carrying pine boughs to a nest, while another pair was observed killing a young mule deer. Examination of the deer indicated that it was in poor condition and apparently suffering from malnutrition. Three, adult, bald eagles were observed during this period. As is the rough-legged hawk, the bald eagle is a winter resident of the Piceance Creek Basin, and by April no bald eagles were present. The great horned owl was the only nocturnal species encountered during these late-winter, field trips. The northern shrike and loggerhead shrike were other raptor-like species present at this time.

From May through July 1975, eight raptor species were observed. The great horned owl was the most frequently encountered species (40 percent). Other species included the red-tailed hawk, turkey vulture, American kestrel, goshawk, Cooper's hawk and saw-whet owl.

The barn owl is an unusual visitor to this portion of western Colorado. A single individual was observed perched on a fence post near the Tract in November 1974. The distribution of home dwellings along Piceance Creek and the barn owl's preference for such habitations may account in part for its presence in this area. Few records of this owl exist for western Colorado. Similarly, only two records of snowy owls

Table V-19 RAPTORS NOTED ON OR CLOSE TO TRACT C-b DURING THE 1974-75 STUDY PERIOD

Species	Seasonal Status*	Number Tallied	% Relative Abundance	Nest Sites Discovered
Turkey vulture	Summer resident	23	5.4	
Goshawk	Undetermined	2	<0.1	√
Cooper's hawk	Summer resident	6	0.1	√
Marsh hawk	Permanent resident	14	3.3	√
Rough-legged hawk	Winter resident	42	9.8	
Red-tailed hawk	Permanent resident	46	10.7	x
Golden eagle	Permanent resident	29	6.8	x
Bald eagle	Winter resident	3	<0.1	
American kestrel	Permanent resident	40	9.3	√
Prairie falcon	Permanent resident	2	<0.1	√
Barn owl	Undetermined	1	<0.1	
Screech owl	Permanent resident	6	0.1	
Great horned owl	Permanent resident	35	8.1	√
Long-eared owl	Permanent resident	2	<0.1	
Snowy owl	Winter resident	2	<0.1	
Saw-whet owl	Permanent resident	2	<0.1	
Raven	Permanent resident	174	40.6	x

x = nest site located in the Tract C-b study area
√ = nest site located in Piceance Basin, but outside the Tract C-b study area
*Definitions of terms used to describe seasonal status follow:

Seasonal Status (based on observations during first year, and supplemented where necessary by literature accounts).

Permanent resident:	A species present during all seasons
Summer resident:	A species present throughout the summer, and assumed to nest in the region
Winter resident:	A species present during winter only
Undetermined:	Insufficient information to judge seasonal status

have been noted in the literature for northwestern Colorado. The presence of this species in southern temperate regions usually coincides with cyclic population patterns exhibited in its arctic breeding area. Peak owl populations coupled with dramatic declines in prey populations produce periodic winter "invasions" of snowy owls into the United States.

The prairie falcon, a species until recently designated as "threatened" by the U. S. Fish and Wildlife Service, was identified on the Tract in February and September 1975. Although considered to be a rare resident in northwestern Colorado, prairie falcons apparently nest in a number of locations in northern portions of the Piceance Creek Basin. No evidence of nesting was found on or close to the Tract.

Field observations made between March and July indicated that raptor activity on the Tract was low during the nesting period. The paucity of observations during the summer census periods is indicative of a small, breeding populations. This contrasts with the importance of the area to wintering raptors.

F. Aquatic Studies

1. Program Description

Monthly collections of fish, benthos, periphyton, water samples and algae from the sampling stations were begun in August, 1974. Sampling was changed to a bimonthly program in January, 1975. Sediment analysis was conducted during some sampling periods.

Eighteen sampling stations were established for this study the location and a description of which are given below. They are shown in Figure V-20.

Station P-0: Piceance Creek, just above the confluence of Piceance and Cow Creek approximately ten miles upstream from the Tract C-b. Substrate consists of mud, gravel and rubble. Several beaver dams exist in this area forming small pools in the creek. Trees and shrubs shade the stream at this station. This station is not a regular sampling station but is used occasionally to study upstream conditions.

Station P-1: Piceance Creek, about one mile upstream from Stewart Gulch Road and approximately one mile upstream of Tract C-b. Substrate consists of small rubble, mud and compacted clay. Grass and low shrubs line the banks.

Station P-2: Piceance Creek, at the Walter Oldland Ranch, below the confluence of Stewart Creek. Substrate consists of mud and compacted clay with some gravel and rubble. Grass and low shrubs line the banks. This station location corresponds roughly to Station PC-1 of Woodling and Kendall (1974).

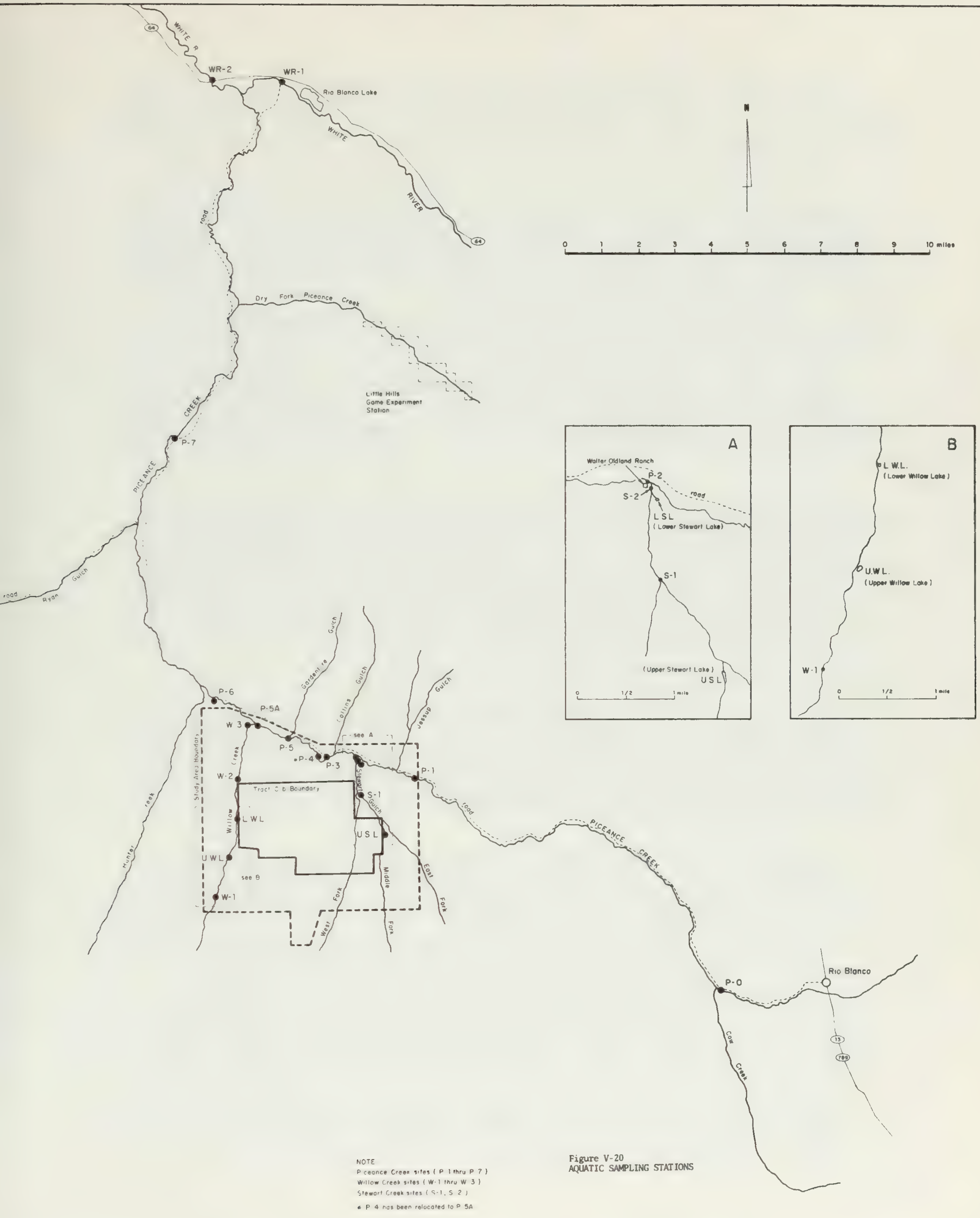


Figure V-20
AQUATIC SAMPLING STATIONS

Station P-3: Piceance Creek, below Sorghum Gulch drainage. Substrate consists of small-to-medium rubble with some mud and clay. Some pools and riffles occur in this stretch, and there is a small waterfall at the upper end of the station. Grass and low shrubs line the banks.

Station P-4: Piceance Creek, below the Redd Ranch, near the air-quality station. Substrate consists of small rubble and mud. Grass and low shrubs line the bank. This station was moved and designated P-5A in November 1974 owing to similarity between Stations P-3, P-4 and P-5. Station P-5A was added to provide a station on a stretch of stream below a waterfall, a habitat of narrow distribution not represented in the other Piceance Creek stations.

Station P-5: Piceance Creek, approximately one mile above the confluence of Will Creek and Piceance Creek. The substrate consists of small flat rubble, mud and compacted clay. Grass and low shrubs line the bank.

Station P-5A: Piceance Creek, approximately 300 yards above the confluence of Willow Creek and Piceance Creek, downstream of the entrance road leading to Tract C-b. Substrate consists of flat rubble, gravel, mud and compacted clay. There is a man-made waterfall approximately 12 feet high resulting from stream diversion at the upper end of the station. There is a pool beneath logs at the base of the waterfall. This station contains shallow riffles below the falls. Grass and small shrubs line the bank. This station was established in November 1974 when Station P-4 was discontinued.

Station P-6: Piceance Creek, approximately one mile below the confluence with Willow Creek, where the Hunter Creek Road crosses the stream, at U.S.G.S. gauging station No. 09306061. Substrate consists of mud, compacted clay and some gravel. Grass and low shrubs line the bank. This station location corresponds roughly with Station PC-2 of Woodling and Kendall (1974).

Station P-7: Piceance Creek, 7.8 miles downstream of Station P-6 along the Piceance Creek Road (Section 21, T1S, R97W). Substrate consists of mud and compacted clay. Grass and low shrubs line the bank.

Station WR-1: White River, approximately one mile above the confluence of Piceance Creek and the White River, where Piceance Creek Road crosses the White River. Substrate consists of small-to-large rubble, boulders and sandy silt in the interstices. Grass and shrubs line the bank. This station location corresponds roughly with Station VI of Everhart and May (1973) and Station 4 of Pennak (1974).

Station WR-2: White River, approximately one mile below the confluence of Piceance Creek and the White River, where State Highway 64

crosses the White River. Substrate consists of small-to-large rubble and sandy silt. The river splits into several channels at times at this station. Grass and willow line the banks. This station corresponds roughly with Station 4 of Pettus (1974) and Station 3 of Pennak (1974).

Station W-1: Willow Creek, approximately one mile upstream from the boundary of Tract C-b. Substrate consists of small, well-embedded rubble. The stream is spring-fed. Width is generally less than three feet and depth less than one foot. Grass and small shrubs line the bank. Watercress and aquatic plants grow in the stream in spring and summer.

Station W-2: Willow Creek, below the confluence of the drainage from Scandard Gulch, just outside the Tract boundary. The substrate consists of sandy silt and gravel. At this station the stream flows through a gulch cut into the meadow floor about 30 feet deep. The stream is generally less than three feet wide and one foot deep. A small waterfall about four feet high marks the upper end of the station. Grass and small shrubs line the banks. Aquatic plants grow in the stream in spring and summer.

Station W-3: Willow Creek, just above the confluence of Willow Creek and Piceance Creek. Substrate consists of gravel and sandy silt. The stream is generally less than three feet wide and one foot deep. Stream banks are lined with grass, shrubs and willows. The stream becomes overgrown in summer in some places. Aquatic plants are much less frequent than at Station W-1 and W-2. This station corresponds roughly to Station WC-1 of Woodling and Kendall (1974).

Station U.W.L.: Upper Willow Lake, approximately one mile downstream from Station W-1. Upper Willow Lake is a shallow, spring-fed, man-made impoundment of about a half-acre. It has a black sandy and mucky bottom rich in organic detritus. A small weir at the opposite end from the spring source drains water into Willow Creek. The lake bank is flat and lined with grass and some shrubs. Aquatic vegetation is abundant in the lake.

Station L.W.L.: Lower Willow Lake, approximately one mile north of Upper Willow Lake is a small (0.1 acre), spring-fed pond about ten feet deep. The spring source is in the bottom of the pond. It has a sandy and mucky bottom rich in organic detritus. Green algal growth is abundant on the lake bottom. The lake bank is flat and grass covered. The lake drains through a small channel into Willow Creek.

Station S-1: Stewart Creek, approximately one mile up Stewart Gulch from the Walter Oldland Ranch, where the road to the west fork of Stewart Gulch crosses Stewart Creek at U.S.G.S. gauging station No. 09306022. Substrate consists of small, embedded rubble and some sandy silt. Stream banks are grass covered. Aquatic plants grow in the stream in spring and summer. Stream width is generally less than three feet and depth less than one foot. Stewart Creek is spring-fed. This station corresponds roughly with Station SC-1, Woodling and Dendall (1974).

Station S-2: Stewart Creek, just upstream from the confluence of Stewart Creek and Piceance Creek. Substrate consists of sandy silt and gravel. This portion of Stewart Creek flows through a grassy meadow. The channel draining lower Stewart Lake joins Stewart Creek at this station.

Station U.S.L.: Upper Stewart Lake, in middle fork of Stewart Creek Gulch. The lake is a spring-fed, man-made impoundment of approximately two acres. The substrate is mud and silt, rich in organic detritus with abundant attached algal growth and aquatic plants. The lake bank is a grassy meadow.

Station L.S.L.: Lower Stewart Lake, located about a quarter-mile south of Piceance Creek Road along the Stewart Gulch Road near U.S.G.S. gauging station No. 00306007 on the Walter Oldland Ranch. Lower Stewart Lake is a man-made impoundment about an acre in size. The substrate consists of small flat rubble and silt. The lake drains into a channel which flows into Stewart Creek. The lake has attached and floating algal growth as well as aquatic plants. Depth of the lake is about ten feet.

2. Methodology

a. Fish

A variable-voltage, DC-battery-operated, backpack shocker, Model BP-2 (Coffelt Electronics Co., Inc., Denver) is used to collect fish from all stream stations bimonthly (Figure V-21). Seines with 0.5-inch mesh are used to collect fish at some stations. These seines are 6 x 100 feet and 6 x 50 feet in size.

A 100-meter (109 yards) stretch of the stream is fished with the backpack shocker at each station. This gives a quantitative measure of number of fish per 100-meter stretch of the stream. Fish are kept in a live-box until they are weighed, measured and tagged. Selected fish are preserved for stomach analysis and examination of reproductive condition. The remainder are returned to the stream.

To detect any migration of fish as stipulated in the oil-shale lease, selected fish are marked and released. In initial collections fish were marked by clipping of one ventral fin. In May 1975 a tagging method of marking was initiated. Tagging of fish allows for identification of individual fish in subsequent recoveries. Two types of tags are being used depending on the size of the fish: Floy Anchor Tags FD-67C and Floy Fingerling Tags FTF-69 (Floy Tag and Mfg., Inc., Seattle). Fish are anesthetized in MS-22 (Tricaine Methane Sulfonate) for tagging and then revived and released. MS-222 (in powder form) is mixed in a container of water at a dosage of 0.5-1.0 gm/gallon water (Bell, 1973). Fish are placed in the container for two to four minutes until they become docile. They are then removed and after tagging are placed in a container of fresh water for three to five minutes until they resume normal swimming activity, then released. Anchor tags are

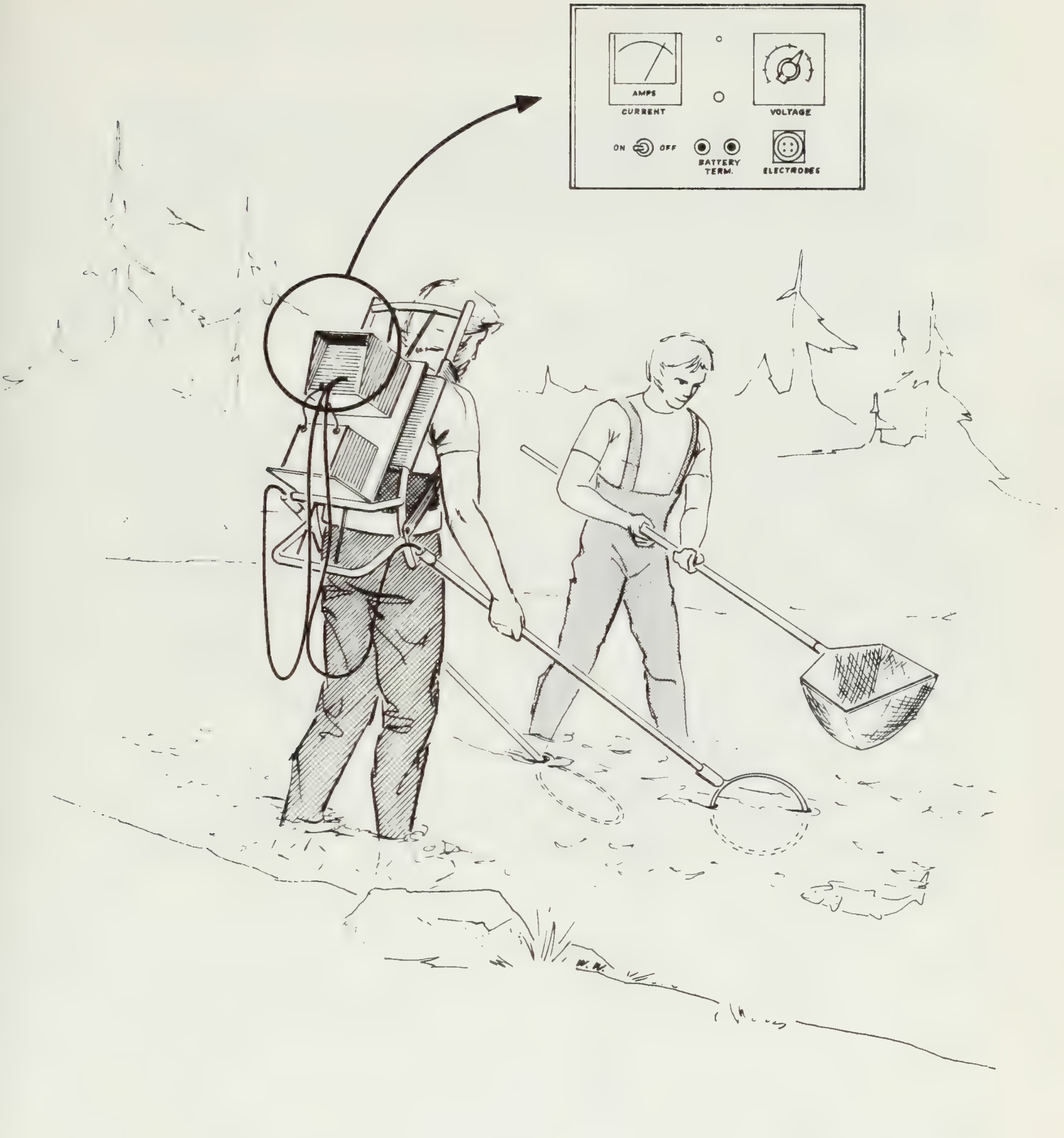


Figure V-21
PORTABLE VARIABLE-VOLTAGE BACKPACK SHOCKER FOR CAPTURING FISH

inserted with a gun on the left side of the fish below the dorsal fin. Fingerling tags are tied through the fish's back anterior to the dorsal fin by use of a steel needle. Figure V-22 shows the method of tagging. The recapture of tagged fish in later samples will provide necessary information on migratory patterns.

Fish retained for further study of reproductive state, determination of sex ratios and stomach analysis are preserved in ten percent formalin solution. Stomachs are removed from the fish when freshly caught and preserved. Food habits of selected fish are determined by stomach analysis using the numerical, percent-by-bulk and volumetric methods as dicussed by Lagler (1956). Organisms are identified and counted,and volume of the stomach contents is determined.

Fecundity estimates of spawning fish are made by the gravimetric method (Lagler, 1956) using subsamples from the ovary for direct enumeration.

b. Population Estimates

The DeLury (Lagler, 1956) and Petersen methods (Lagler, 1956; Ricker, 1968) are being used to estimate fish populations. The DeLury method depends on the reduction in the catch in successive fishing efforts but cannot be used unless the decrease in population size is reflected in the successive efforts. This method involves fitting a regression line to the catch per unit-of-effort data and extrapolating to estimate the population. The computation method using the formulae developed by Zippin (1958) for the multinomial method is used. The population estimate and confidence interval (95 percent level) are computed treating each species separately. The estimates for each species are combined to get an overall, total, population estimate. At selected stations a 100-meter stretch of stream is blocked off with seines, and electrofishing is conducted for three, successive, fishing efforts.

The mark-recapture method (Petersen method) involves the capture and release of marked (or tagged) fish into the population and the recapture of marked fish in subsequent resampling of the population. Tagging and recapture are being conducted for the duration of the study. The population size is calculated by the formula:

$$P = M(u+r)/r$$

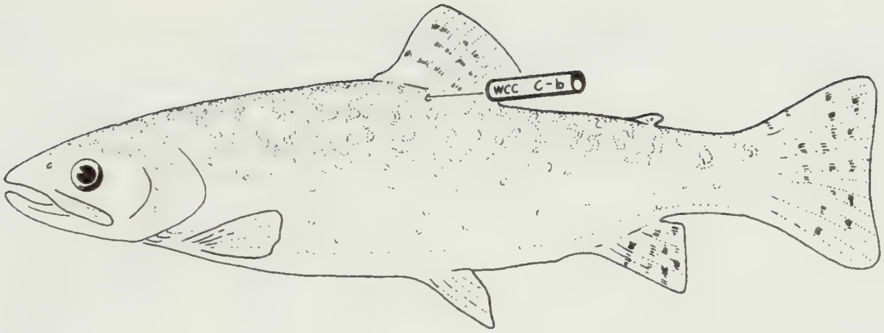
where: P = population

M = number of marked fish released

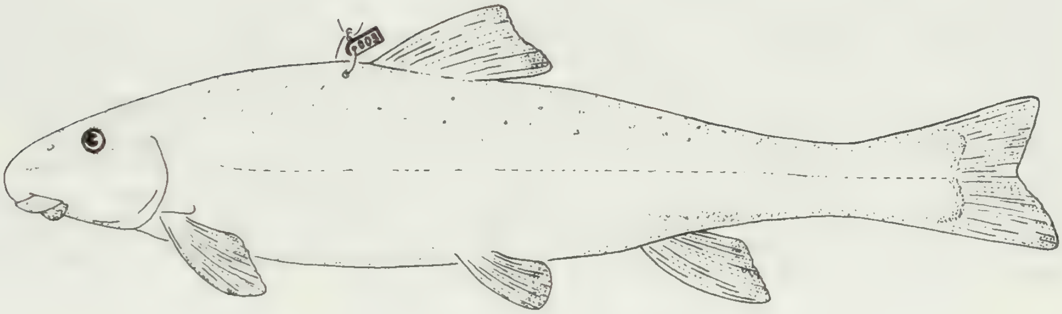
u = unmarked fish captured

r = marked fish captured

There are assumptions which must be made for both methods. For the DeLury method they are: 1) the population is closed (effects of migration and mortality are negligible); 2) the units-of-effort do not compete with one another or else they are constant during the period



a. Anchor tag attached to trout.



b. Fingerling tag attached to sucker.

Figure V-22
TYPES OF TAGS USED IN FISH STUDIES

involved; and 3) response of fish to the gear (catchability) remains constant for the period under investigation. With this method fish caught in each trial must not be returned to the stream or lake prior to completion of fishing efforts.

The assumptions made for the Petersen estimate are: 1) marked fish do not lose their marks throughout the period of study and they are recognizable on recapture; 2) marked individuals are randomly redistributed throughout the population, or that effort spent in catching the fish is proportional to the density of the population throughout the body of water; 3) marked and unmarked fish are susceptible to the same degree of capture; 4) numbers of fish entering the experiment are not increased as a result of recruitment from growth or immigration; and 5) losses through death or emigration are the same for marked and unmarked fish (Lagler, 1956). In the Petersen method captured fish may be returned to the stream or lake and continued marking may be carried out.

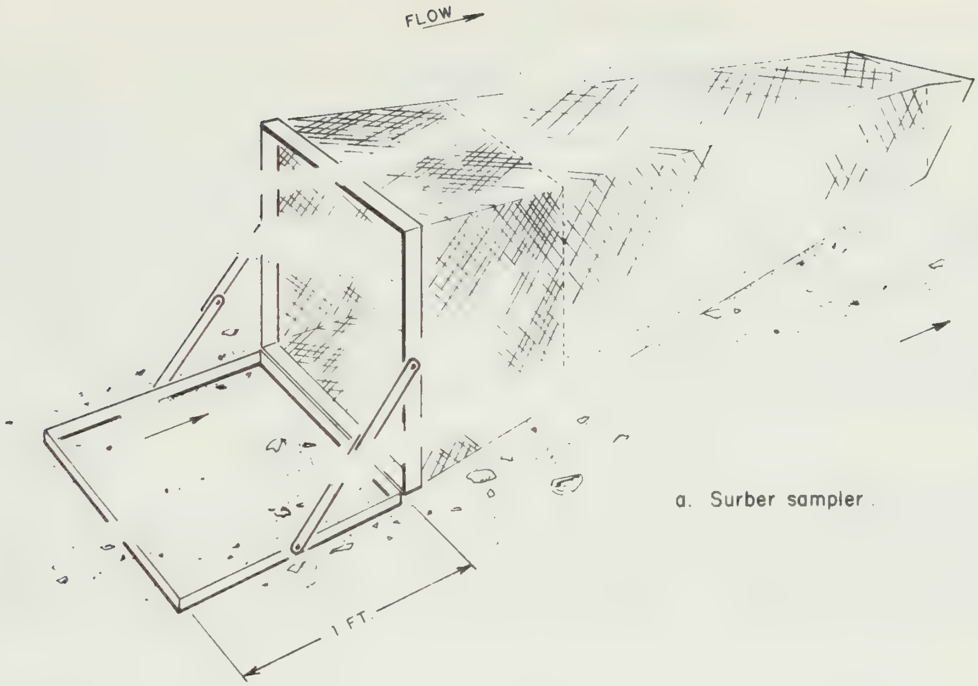
c. Benthos

Benthic macroinvertebrates (bottom-dwelling organisms) are collected at all stream stations with a Surber square-foot stream-bottom sampler (Needham and Needham, 1962). The apparatus utilizes the stream's current to wash the benthic organisms into a net (Figure V-23). The larger stones enclosed in the square-foot area are washed and discarded. The remaining substrate is gently churned up to dislodge burrowing organisms. At lake stations a one-square-foot area is strained through the Surber net. Samples are taken in triplicate at each station for statistical comparison. Samples are preserved in isopropyl alcohol and returned to the laboratory. Since many other studies have utilized the Surber sampler, the results of this survey will have comparative value. Identification, enumeration and biomass determinations (weight/square foot) are conducted in the laboratory.

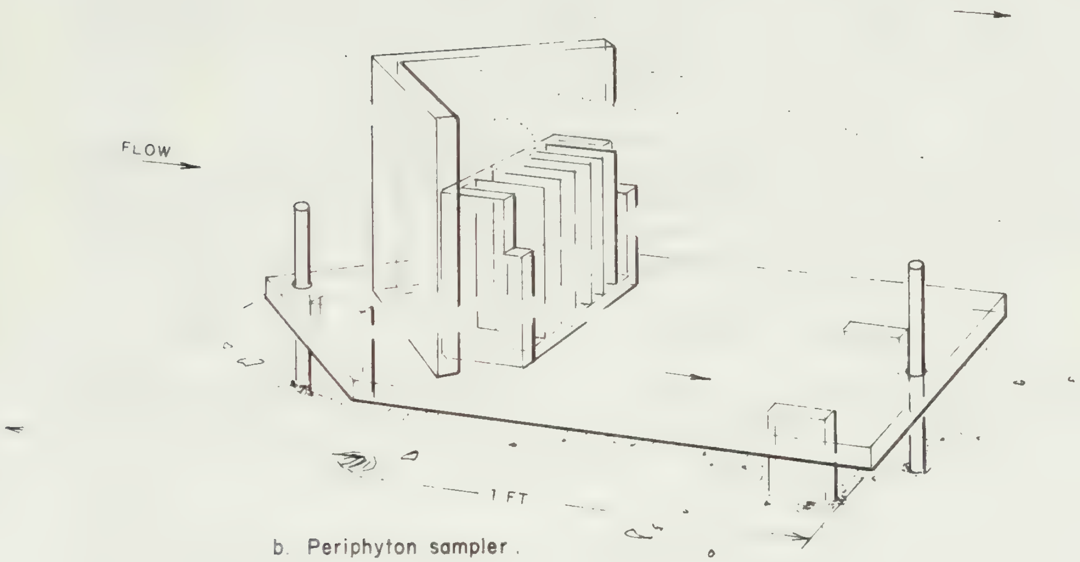
d. Periphyton

Periphyton (attached plants and microinvertebrates) are collected from each station by removing six, glass slides (1 x 3 inches) from a plexiglass holder which has been immersed in the stream for about a month (Figure V-23). Three of the six slides are preserved in vials of formalin for later taxonomic work. The other three slides are air-dried and stored for biomass analysis. This entails drying overnight at 110°C and scraping the periphyton from each slide separately into a prepared weighing dish. The material is weighed to the nearest ten-thousandth of a gram (0.0001). The weights are converted to grams per square meter by the formula:

$$\frac{\text{mean weight of samples (gm)}}{\text{area of slide (cm}^2\text{)}} \times 10{,}000$$



a. Surber sampler.



b. Periphyton sampler.

Figure V-23
DEVICES FOR SAMPLING BENTHOS AND PERIPHYTON

e. Water Quality

Water samples are collected bimonthly at each station. The samples are taken near the third Wednesday of the month so as to coincide with water quality analyses performed by the U. S. Geological Survey (U.S.G.S.) for the same area. Measurements of dissolved oxygen and temperature (using a Yellow Springs dissolved-oxygen meter, Model 51A), pH (using a Photovolt Meter, Model 125) and specific conductivity (using a DREL-2 Hach Kit), are made in the field at the time of collection. Water samples for further analysis are placed in one-quart, plastic containers and put on ice. Laboratory analysis consists of quantitative determination of 33 parameters (Table V-20). Procedures conform to those specified in APHA Standard Methods (1971) and EPA Publication 16020-07/71.

f. Primary Productivity

Planktonic, primary productivity was estimated in the four lake stations using the light and dark bottle technique. Two light (transparent) and two dark (opaque) bottles were exposed for up to 24 hours at each lake station. Dissolved oxygen was determined after 8 and 24 hours exposure by the Azide modification of the Winkler method.

This method involves treatment of water samples in the field with manganous sulfate and an alkaline iodide solution, followed by acidification with sulfuric acid to release free iodine equivalent to the dissolved oxygen in solution. A 100 ml portion of the sample is titrated in the laboratory with P.A.O. (Phenylarsine Oxide) to determine the amount of dissolved oxygen (APHA Standard Methods, 1971).

Periphyton primary productivity in the streams and lakes is being measured by the biomass accumulation technique (APHA Standard Methods, 1971; Sladecek and Sladeckova, 1964). This method utilizes accumulation of periphyton on glass slides. Net productivity is determined from the ash-free weight of periphyton material accumulated per unit area.

g. Sediment Samples

Sediment Samples were collected from all stream and lake stations beginning in May 1975. Surface samples were dug by hand trowel to a depth of about six inches. Samples were sealed in bags and placed on ice for analysis in the laboratory.

Laboratory analyses included determinations of moisture content, C.O.D. (Chemical oxygen demand), TKN (Total Kjeldahl Nitrogen) and volatile solids (APHA Standard Methods, 1971). Subsamples were dried in an oven and sieved through U. S. Standard sieves on a Tyler shaker. Spectrographic screen analysis for heavy metals was conducted during one, sediment-sampling period.

Table V-20 WATER QUALITY ANALYSIS METHODS

Minerals	Method	Reference
Cations		
Calcium	EDTA Titrimetric Method	APHA*
Magnesium	EDTA Titrimetric Method	APHA
Sodium	Flame Photometric Method	APHA
Potassium	Flame Photometric Method	APHA
Ammonia	Nesslerization Method	APHA
Anions		
Hydroxide (OH)	Alkalinity	APHA
Carbonate	Alkalinity	APHA
Bicarbonate	Alkalinity	APHA
Sulfate	Gravimetric Method with drying of residue	APHA
Chloride	Mercuric Nitrate Method	APHA
Nitrate	Brucine Method (tentative)	APHA
Organics		
Ortho Phosphate	Stannous Chloride Method	APHA
Ammonia (N)	Nesslerization Method	APHA
Inorganics		
Boron	Carmine Method	APHA
Silica	Molybdosilicate Method	APHA
Iron	Phenanthroline Method	APHA
Manganese	Persulfate Method	APHA
Nitrate (N)	Brucine Method (tentative)	APHA
Nitrite (N)	Nitrogen (Nitrite)	APHA
Alkalinity ((2(0_3)	Alkalinity	APHA
Hardness ((2(0_3)	EDTA Titrimetric Method	APHA
Dissolved Solids	Filtrable Residue @ 180°C	APHA
pH	pH Value	APHA
Conductivity	Specific Conductance	APHA
Microbiology		
Standard Plate Count	Standard Plate Count @ 35°C	APHA
Coliform	Standard Total Coliform MPN Test	APHA
Fecal Coliform	Fecal Coliform MPN Procedure	APHA
Fecal Streptococci	Multiple-Tube Technic	APHA
Pathogens	Isolation of Enteric Bacteria (MacConkey's Agar)	*Microbiology* Zinsser (13th Ed.)
Sediments		
% Moisture	Total Residue on Evaporation	APHA
TKN	Nitrogen (Total Kjeldahl)	APHA
COD	Oxygen Demand (Chemical)	APHA
Volatile Solids	Total Volatile and Fixed Residue	APHA

* APHA *Standard Methods*, 1971

h. Springs and Seeps

As part of the baseline studies, springs and seeps in the vicinity of the Tract are being identified and examined. They are studied to determine aquatic organisms which may be present. In addition selected water quality data are collected at each site for comparison with existing water quality data at aquatic sampling stations. Some of the major springs are incorporated into the aquatic sampling program as regular lake sampling stations. Others are seasonal in nature and are examined on an irregular basis.

3. Results and Discussion

Piceance Creek is generally characterized by a meandering stream channel, fluctuating flows, high levels of dissolved solids, high turbidity (during spring runoff), silted rock and gravel substrates at certain times of the year and infrequent pool and shelter areas for fish. These factors make much of the habitat unsuitable for large, gamefish populations. At certain times rock and gravel substrates predominate with low silt levels. However, game fish that occur in Piceance Creek appear healthy and in good condition. It is evident that the aquatic environment of Piceance Creek favors less desirable but more highly adaptable, non-game species such as the mountain sucker and speckled dace. Willow Creek and Stewart Creek are small, spring-fed streams similar to Piceance Creek in terms of water quality and substrate. However, turbidity and siltation are not a problem in these streams as they are in Piceance Creek. The White River is a large river environment with lower levels of dissolved solids. Flow rates are increased significantly during runoff.

a. Fish

Three species of trout occur in the vicinity of the Tract: the Rainbow (Salmo gairdneri), the Brook (Salvelinus fontinalis) and the Brown (Salmo trutta). Other fish include the mountain sucker (Catostomus platyrhynchus), speckled dace (Rhinichthys osculus), mottled sculpin (Cottus bairdi) and mountain white fish (Prosopium williamsoni). Fish species collected in the study streams are listed in Table V-21. In the vicinity of the Tract Piceance Creek supports higher populations of fish than are found in Stewart Creek and Willow Creek. These are primarily mountain sucker, speckled dace and brook trout. A few rainbow trout have been collected in the middle reaches of Piceance Creek.

Differences in numbers of fish occur in various areas of Piceance Creek. The areas with a rock and gravel substrate and a combination of riffles and pools offer better habitat for fish than do other areas. There is a general trend for numbers of fish to increase in an upstream direction. In terms of fish species the upstream portions of Piceance Creek near the Tract contain more fish than downstream waters.

Stewart and Willow Creeks support some brook trout, mountain suckers and speckled dace. Lower Stewart Lake and its drainage channel,

Table V-21 FISH COLLECTED FROM PICEANCE CREEK, STEWART CREEK, WILLOW CREEK AND THE WHITE RIVER

Scientific Name[1]	Common Name[1]
Salmo trutta	Brown trout
Salmo gairdneri	Rainbow trout
Salvelinus fontinalis	Brook trout
Prosopium williamsoni	Mountain whitefish
Rhinichthys osculus	Speckled dace
Catostomus latipinnus	Flannelmouth sucker
Catostomus platryhynchus	Mountain sucker
Cottus bairdi	Mottled sculpin

(1) American Fisheries Society. 1970. A List of Common and Scientific Names of Fishes from the United States and Canada. 3rd Ed. Spec. Pub. No. 6.

which empties into Stewart Creek just above its confluence with Piceance Creek, support a fair size population of brook trout. The three other lakes studies contain no fish.

The White River at its confluence with Piceance Creek has a river environment compared to the small-stream environment of Piceance Creek. However, cold-water fish species are more abundant upstream near headwater regions of the White River than in the vicinity of Piceance Creek. Mottled sculpin is abundant in the White River. In addition mountain whitefish, flannelmouth suckers and speckled dace have been collected. Sampling in the White River is difficult and data obtained on fish species of the White River are sketchy compared to the other areas under study. All fish captured in the first year are listed by station in Quarterly Data Report #5.

Mountain suckers are found throughout Piceance Creek. This is reported to be their only known area of occurrence in Colorado (R. Behnke, Personal communication; Smith, 1966). Mountain suckers spawn in late spring and early summer in Piceance Creek. This is consistent with spawning habits reported for the mountain sucker by Smith (1966), Hauser (1969), Sigler and Miller (1963) and Baxter and Simon (1970).

Newly-hatched fish were collected in July along with spawning fish. Males develop reddish-bands on their sides and tuberculate caudal and anal fins during spawning. Females also show some coloration. Fecundity studies on female fish indicate several spawnings per year. Ovaries contained equal quantities of ripe and developing eggs. Fecundity estimates for female fish of 129-to-190-millimeters total length ranged from approximately 2,600 to 8,699 eggs produced per year. More mountain suckers were observed in spawning condition in upstream portions of Piceance Creek than in downstream sections, indicating more favorable spawning conditions may exist upstream. Analysis of reproductive condition in mountain suckers has shown that in Piceance Creek most fish are mature and able to spawn at 100 mm total length. The smallest mature fish captured was 70 mm total length. All fish less than 70 mm total length were immature. These sizes are smaller than those found by Hauser (1969) for mountain suckers in Montana. Length-weight relationships were plotted and linear regression lines fitted to the data for mountain suckers (Figure V-24). Two growth stanzas were arbitrarily selected based on visual inspection as discussed by Ricker (1968). Mature fish increased in weight at a faster rate relative to length than immature fish. Average lengths based on age groups for mountain suckers from Piceance Creek agreed very well with comparable data collected by Hauser (1969). Preliminary analysis of computed condition-factors (Ricker, 1968) for mountain suckers of selected size ranges (assuming allometric growth) indicates that fish are in the best condition from July through November with the poorest condition occurring around January. Condition is improving again by May.

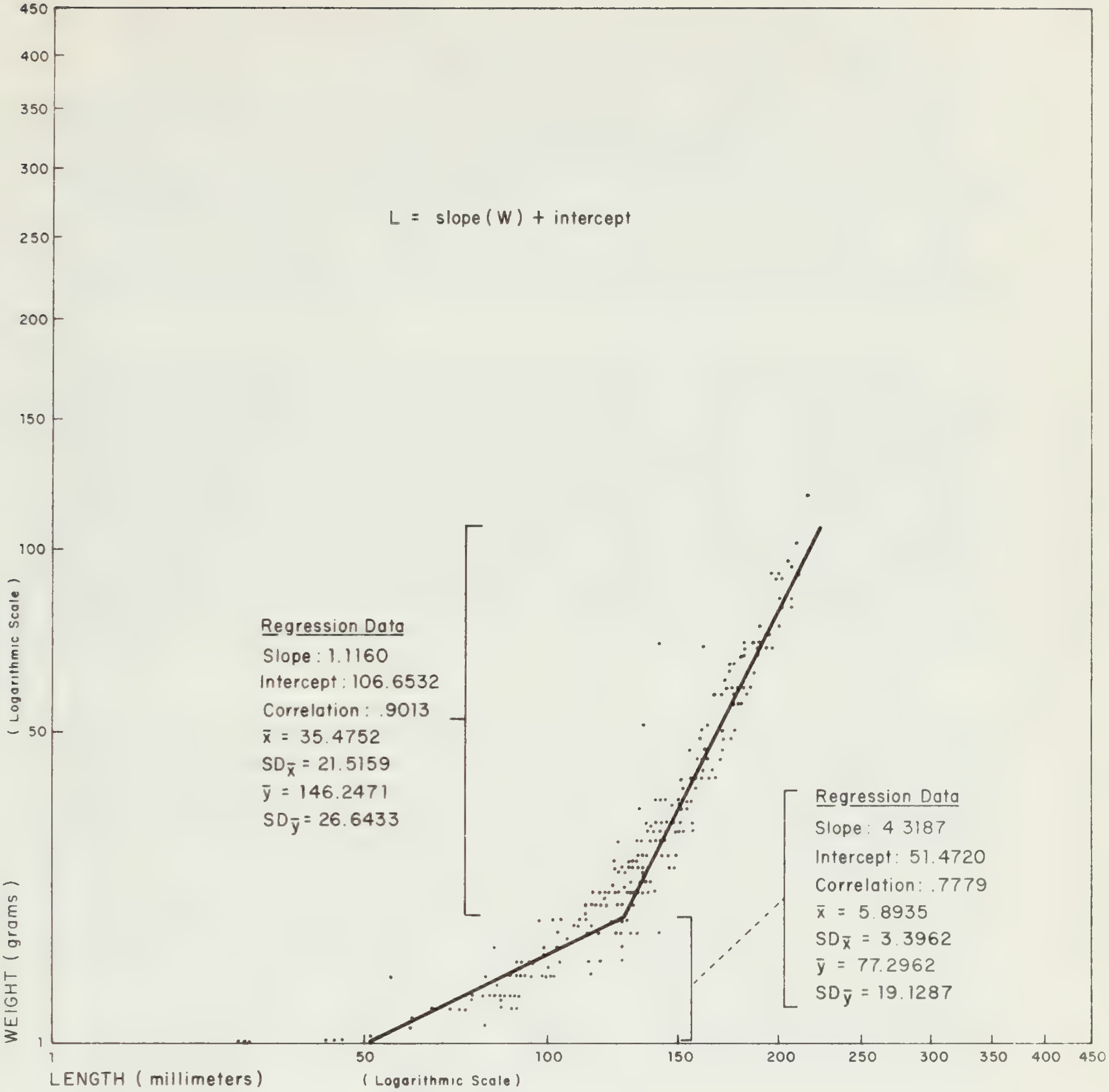


Figure V-24
LENGTH-WEIGHT LINEAR REGRESSION FOR MOUNTAIN SUCKERS FROM PICEANCE BASIN (two growth stanzas computed)

The mountain sucker population in Piceance Creek appears to be well established and thriving. Estimates of abundance of mountain sucker range as high as 68 fish per 100-meter stretch of Piceance Creek in the vicinity of the Tract. These estimates vary at different locations within Piceance Creek and range from 23 $\pm$ 7 to 68 $\pm$ 38 fish per 100-meter stretch of stream depending on station location. Estimates are based on the DeLury method of determining population size. Abundance and confidence intervals are computed by the method outlined by Zippin (1958). Scale aging of mountain suckers has determined fish from age groups 0+ to 4+ (Table V-22) comprise the majority of the mountain sucker population. Stomach analyses indicate the major food source to be algae, plant material and some insects.

Speckled dace are sampled with mountain suckers in Piceance Creek. Spawning occurs in late spring and summer. Males develop reddish fins and coloration on the lower jaw during spawning. Speckled dace appear to spawn several times as eggs examined were not all at the same stage of development. The number of eggs produced by the speckled dace is similar to the number produced by the mountain sucker. Fecundity estimates for female fish 87 to 109 mm total length ranged from approximately 2,700 to 7,000 eggs per year. Estimates of speckled-dace abundance range from 13 $\pm$ 8 to 63 $\pm$ 32 fish per 100-meter stretch of Piceance Creek in the vicinity of the Tract depending on station location. Speckled dace are also collected from the White River and some Stewart and Willow Creek stations.

Brook trout are the predominant trout species in the Tract vicinity. A few rainbow and brown trout have been collected. Brook trout occur in Stewart Creek, in Lower Stewart Lake and in the channel that drains Lower Stewart Lake. In addition brook trout occur at some stations in Piceance Creek. Suitable habitat varies along Piceance Creek and fish abundance reflects habitat suitability. Brook trout spawn in the fall. Young fingerling brook trout have been collected in the spring in Stewart Creek and Lower Stewart Lake indicating that natural spawning occurs in these areas. Spawning brook trout were captured in Willow Creek and Piceance Creek in September and November. Spawning took place primarily in October and early November in the Tract vicinity. Several large spawning fish were captured in the fall in Piceance Creek below a barrier to upstream migration. It seems likely that these fish may have migrated upstream from the White River to spawn. Egg diameters from one spawning female captured in November ranged from 4.0 to 5.0 mm. Similar egg sizes are reported for brook trout by Scott and Crossman (1973). Fecundity estimates were made for several female brook trout ranging in size from 225 to 297 mm total length. Fecundity estimates ranged from 926 to 1,091 eggs produced which agrees with findings by other workers (Scott and Crossman, 1973; Vladykov, 1956). Analysis of brook trout feeding habits in the vicinity of the Tract indicate they feed primarily on aquatic insects. Chironomids and other Dipterans were the most abundant food taken; in addition, Ephemeropterans, Coleopterans, Tricopterans, Amphipods, Homopterans and Oligochaetes were consumed. Griffith (1974), Wurtsbaugh, et al, (1975) and Miller (1974) reported similar feeding habits.

Table V-22 LENGTH-AGE RELATIONSHIP OF MOUNTAIN SUCKERS CAPTURED AT PICEANCE BASIN STATIONS, 1974-75.

	Age[1] (years)[2]				
Length (mm)	0+	1+	2+	3+	4+
10					
20					
30					
40					
50	1				
60					
70					
80	2				
90	4	3			
100	1	3			
110	2	3			
120		4	4	2	
130		3	9	2	
140		3	9	4	
150			6	9	
160			2	4	1
170			4	1	
180			4	1	1
190				2	1
200				1	
210				1	
220					
230					
240					
250					
260					
270					
280					

1. Ages determined by scale readings
2. Based on Ricker (1968)

Estimates of brook trout abundance range from 0 to 10 ± 8 fish per 100-meter stretch of stream in the vicinity of the Tract, depending on station location. At times populations of approximately 100 brook trout inhabit Lower Stewart Lake. Scale aging of brook trout has indicated that most fish captured are in the age groups 0+ and 1+ (Ricker, 1968). Several of the larger fish have been in age groups 2+ to 4+ (Table V-23). It is reported that brook trout seldom live beyond five years and never beyond eight years in the wild (Scott and Crossman, 1973).

Length-weight relationships were plotted and linear regression lines fitted to the data for brook trout (Figure V-25). Two growth stanzas were arbitrarily selected based on visual inspection as discussed by Ricker (1968). Larger fish increased in weight at a faster rate relative to length than immature fish. Brook trout growth rates vary widely depending on the type of habitat (Scott and Crossman, 1973).

Preliminary analysis of computed condition factors (Ricker, 1968) for brook trout of selected size ranges (assuming allometric growth) indicates that fish are in the best condition during late summer with the poorest condition occuring around January. Condition is improving in spring and decreasing in late fall after spawning.

Fish are marked and released in order to study migration patterns. Results of the marking and recapture program are presented in Quarterly Data Report #5. The number of tagged fish recoveries has been insufficient to date to make an analysis of any migration that may occur.

To date no endo- or ectoparasites have been detected from fish collected. Some fish have shown indications of eroded fins and, in one case, lacerations. These instances have been rare occurrences. Most fish collected are in good condition.

b. Benthos

The term "benthos" is used to designate the group of organisms that live on the bottom substrate of bodies of water. Benthic invertebrates are useful as general indicators of the quality of aquatic habitat in the region relative to reproduction of aquatic fauna. Benthos are sampled bimonthly from all stream and lake stations using a Surber, square-foot, bottom sampler. The large number of organisms occurring at some sample sites in the Tract drainage indicates a good production potential for aquatic invertebrates.

Benthic invertebrates in the vicinity of the Tract consist primarily of Annelids, Arthropods and Molluscs. The Arthropods, especially the aquatic insects, are most numerous. The type of organisms that occur suggests a good production of fish food types. The major Arthropod orders utilized as fish food (Diptera, Plecoptera, Tricoptera, Coleoptera and Ephemeroptera) are represented at all sampling stations. In the vicinity of the Tract total numbers and biomass of these organisms undergo seasonal fluctuations. The greatest abundance of organisms occurs in summer and fall with lower levels during winter. The poorest, benthic-species' composition occurs downstream of the Tract in areas of mud and

Table V-23 LENGTH-AGE RELATIONSHIP OF BROOK TROUT CAPTURED AT PICEANCE BASIN STATIONS, 1974-75.

	Age[1] (years)[2]				
Length (mm)	0+	1+	2+	3+	4+
10					
20					
30					
40					
50					
60					
70					
80					
90	1				
100	3				
110	9				
120	7				
130	6	2			
140	4	3			
150	2	2			
160					
170	1				
180		1			
190		1	1		
200		2			
210	1				
220					
230		1			
240		1			
250		1			
260					
270		1			
280					
290		1			
300					
310		1			
320			1		
330					
340				1	
350					
360					
370					
380					
390					1
400					
410					
420					
430					

1. Ages determined by scale readings
2. Based on Ricker (1968)

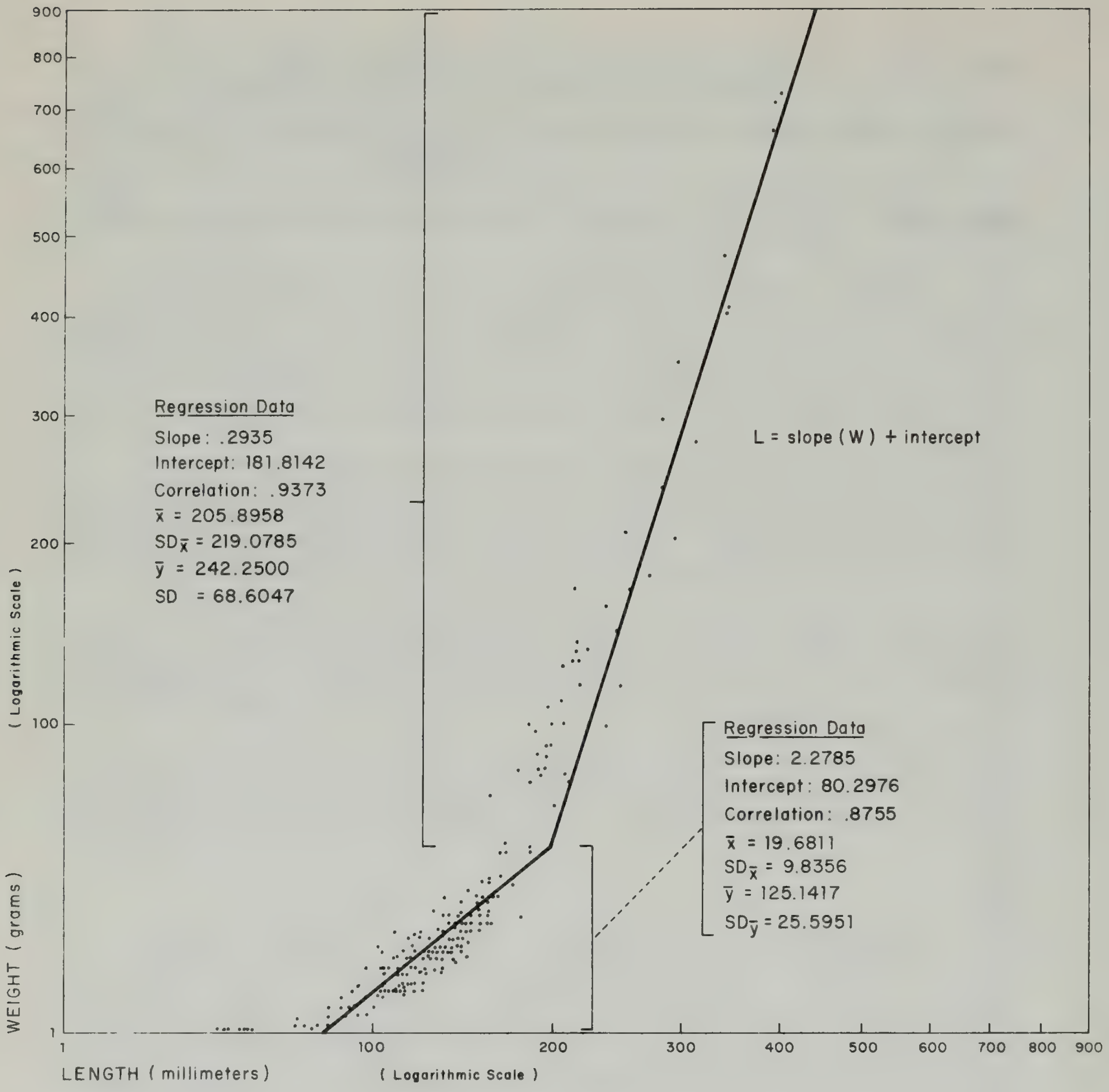


Figure V-25
LENGTH-WEIGHT LINEAR REGRESSION FOR BROOK TROUT FROM PICEANCE BASIN (two growth stanzas computed)

clay substrate which provides poor habitat for benthic fauna.

The lake stations sampled generally provide good production of benthic invertebrates. Suitable habitat for benthos varies along Piceance Creek as reflected by benthic abundance and diversity. The areas with a rock substrate offer better habitat for benthos than do other areas.

Number of benthos collected by the month, classified by order, has been plotted along with biomass relative to Lagler's (1956) classifications of food grade in streams (Figures V-26 through V-31). In Lagler's (1956) discussion of the categories he points out that numbers alone do not give a complete picture of the food supply. Samples may contain three to four hundred mayfly nymphs and measure less than 0.5 gm whereas another sample may contain only thirty or forty organisms, some of which may be large stonefly nymphs or tipulid larvae and measure four or five grams. The latter would presumably produce more fish. Therefore, to qualify in any food grade both the numerical and biomass values must be within the required range for that food grade (Lagler, 1956). Almost all of the stations, with the exception of some Stewart Creek stations and the White River at certain times of the year, would be classified in the "poor" food grade (Figures V-26 to V-31) owing to low biomass values. However, it appears that lack of suitable habitat, rather than food, limits trout distribution in the vicinity of the Tract.

Species-diversity indices were calculated each sampling period for each station during the study using the formula:

$$H' = \sum_{i=1}^{s} P_i \log_2 P_i$$

where P_i is the proportion, P, of the i^{th} species in the sample and s is the number of species.

Theoretically the diversity index provides an estimate of the complexity of the biological community and reflects structural and organizational features which lend it overall stability. It is felt that the greater the number of species in a community, the more complex the energy flow pathways become. If any one pathway were eliminated, no great harm to the system would result since other energy pathways exist. The system thus maintains its stability. In a very simple community of few species, on the other hand, removing only one energy pathway could cause a loss of stability in the community.

The diversity index, H', has two components: (1) number of species and (2) the proportion (evenness) of individuals among species, both of which increase diversity. Intuitively, one would accept that a sample of ten species is more diverse than a sample of two species; therefore, H' would increase. The higher the H' value the greater the number of species, or evenness component, and the more stable or complex the

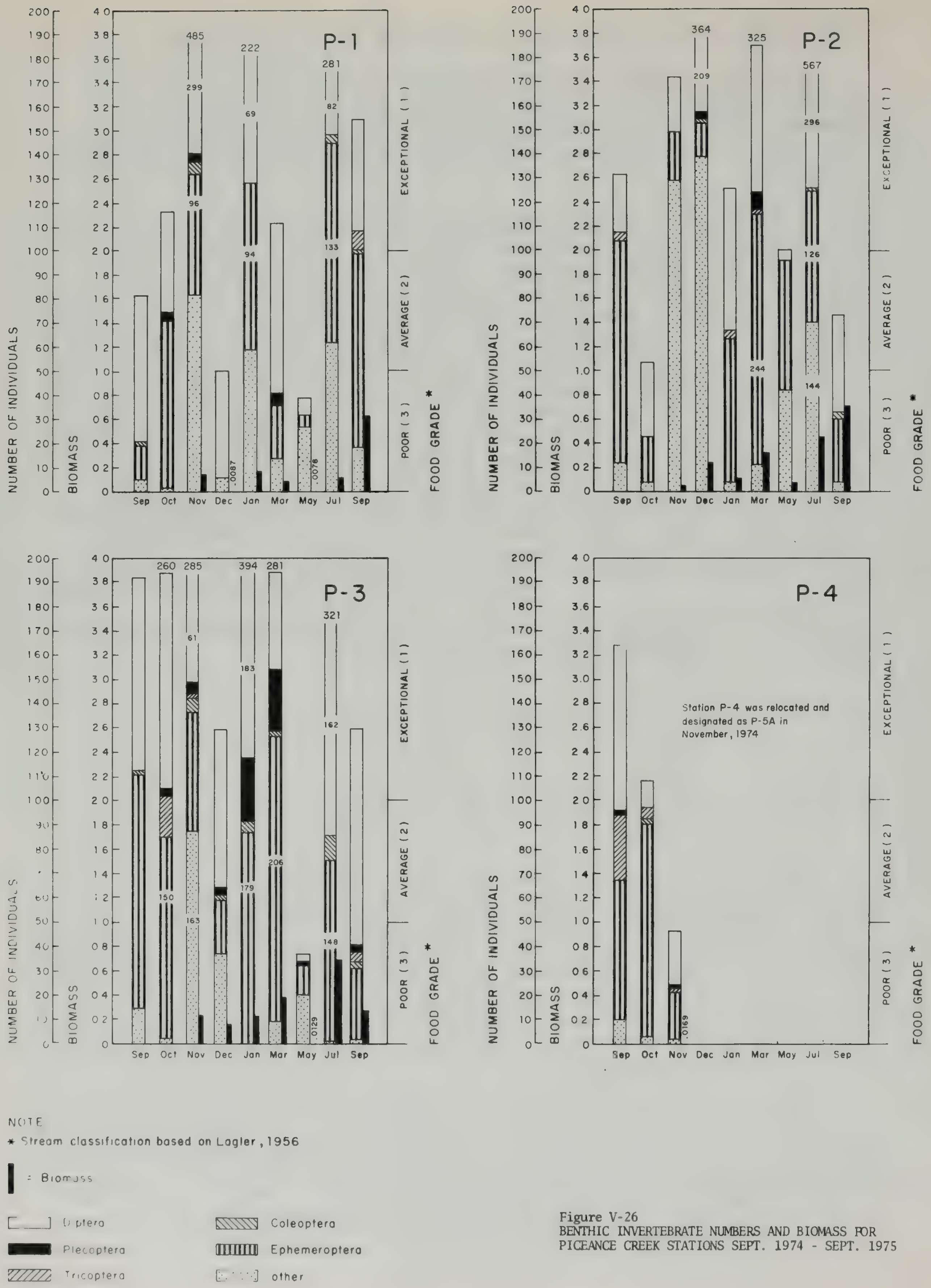
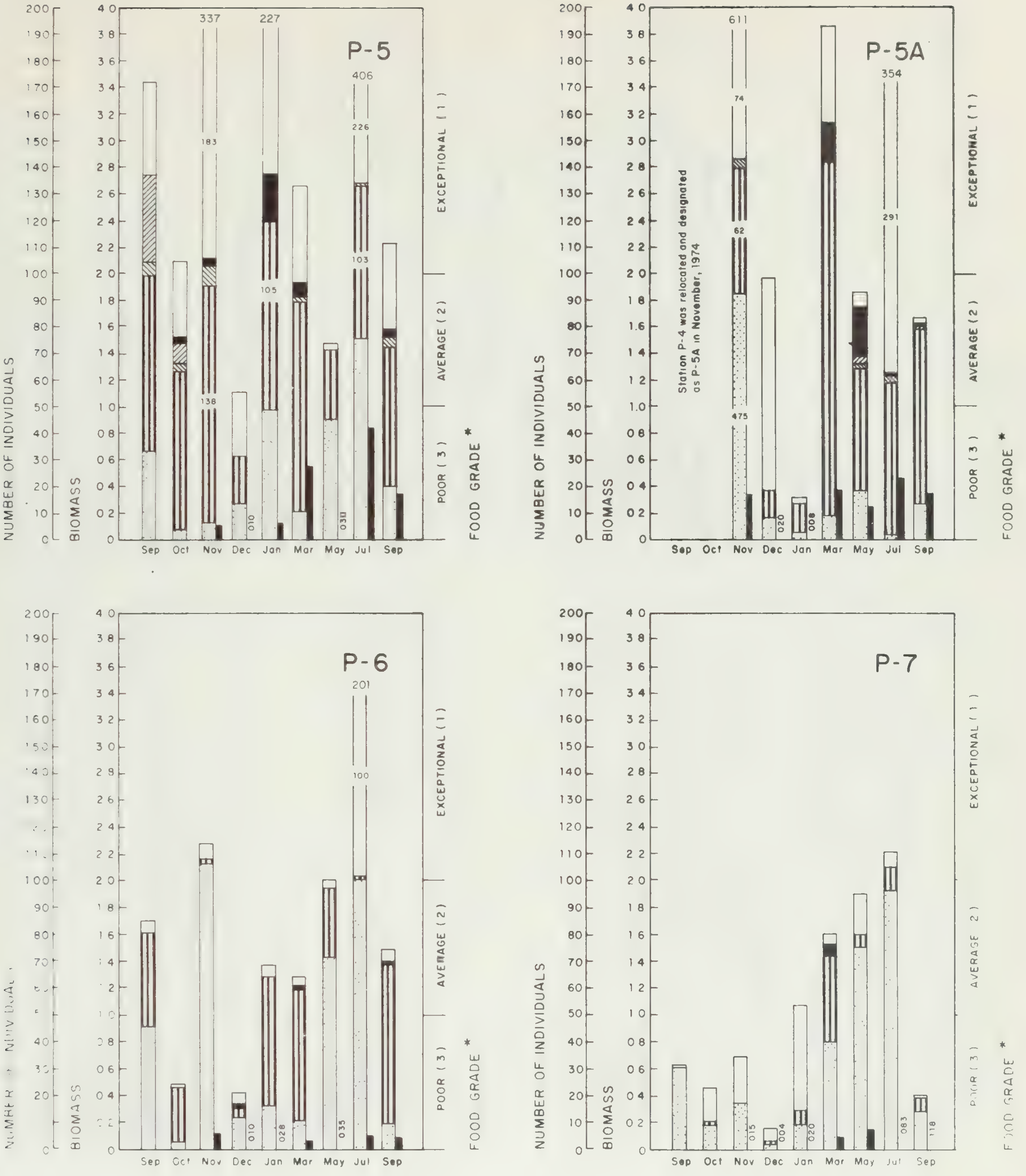


Figure V-26
BENTHIC INVERTEBRATE NUMBERS AND BIOMASS FOR PICEANCE CREEK STATIONS SEPT. 1974 - SEPT. 1975



NOTE

* Stream classification based on Lagler, 1956

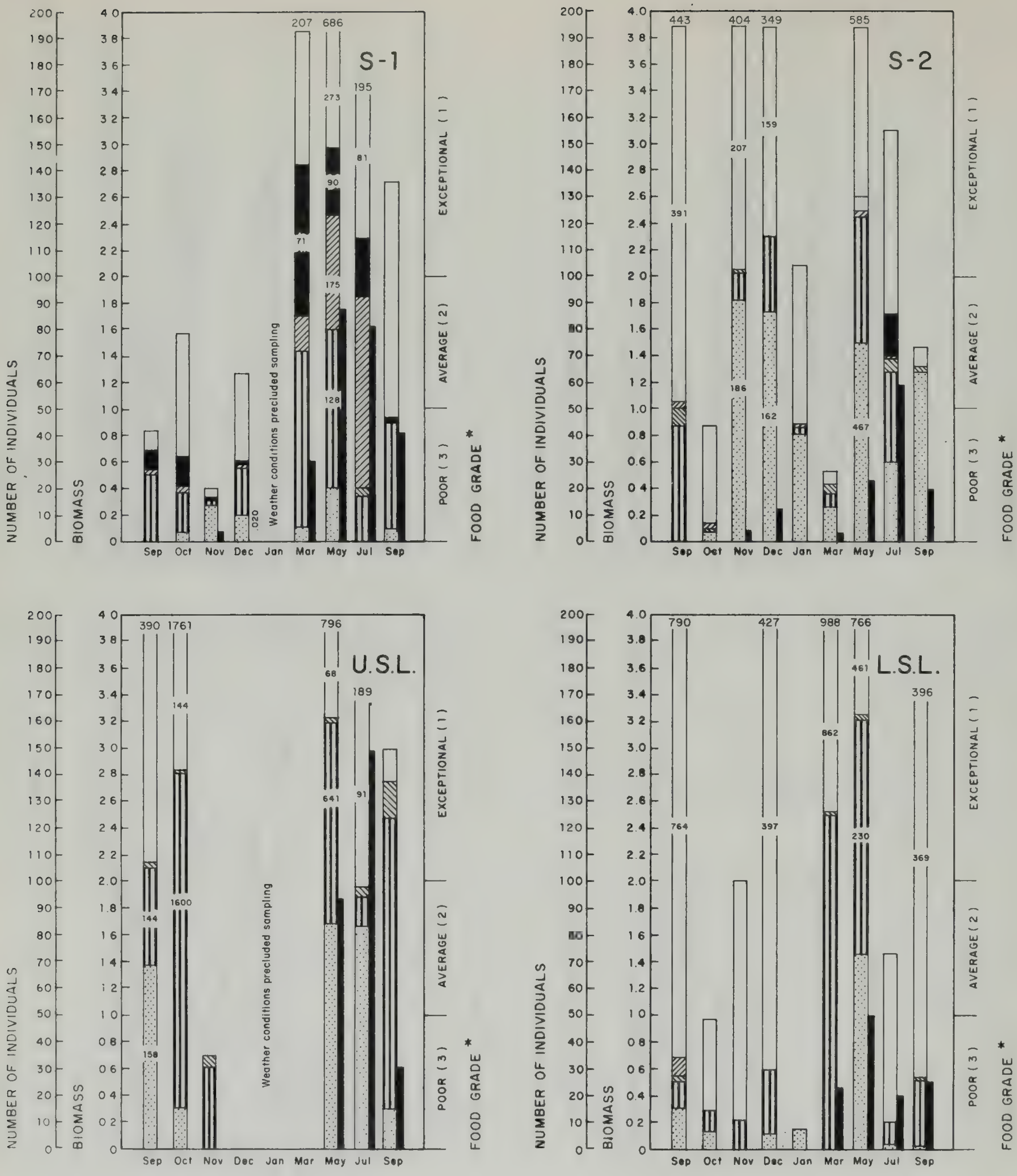
Biomass

Diptera — Coleoptera

Plecoptera — Ephemeroptera

Trichoptera — other

Figure V-27
BENTHIC INVERTEBRATE NUMBERS AND BIOMASS FOR PICEANCE CREEK STATIONS SEPT. 1974 - SEPT. 1975



NOTE

* Stream classification based on Lagler, 1956.

= Biomass

Diptera

Plecoptera

Tricoptera

Coleoptera

Ephemeroptera

other

Figure V-28
BENTHIC INVERTEBRATE NUMBERS AND BIOMASS FOR STEWART CREEK AND LAKE STATIONS SEPT. 1974 - SEPT. 1975

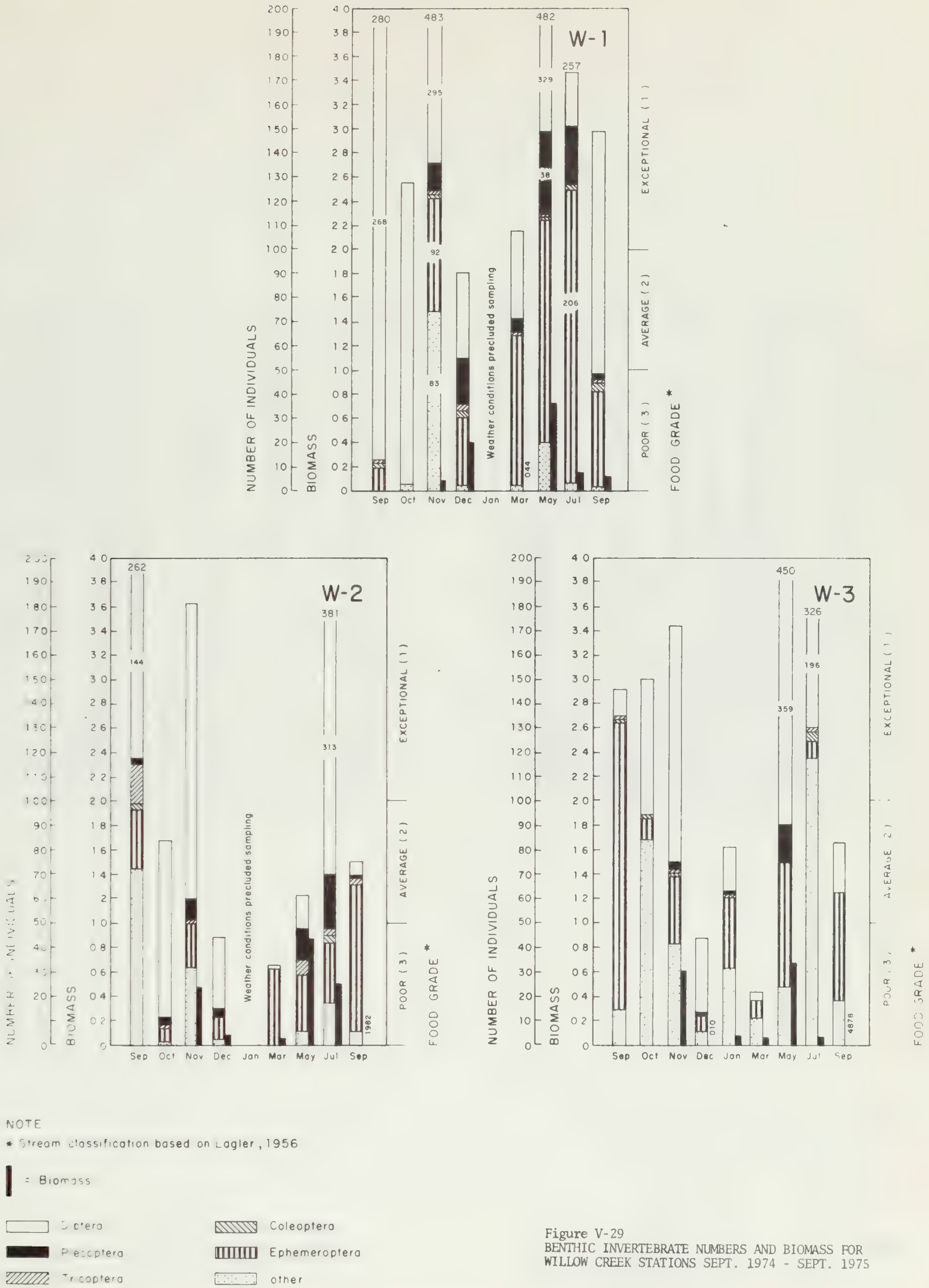
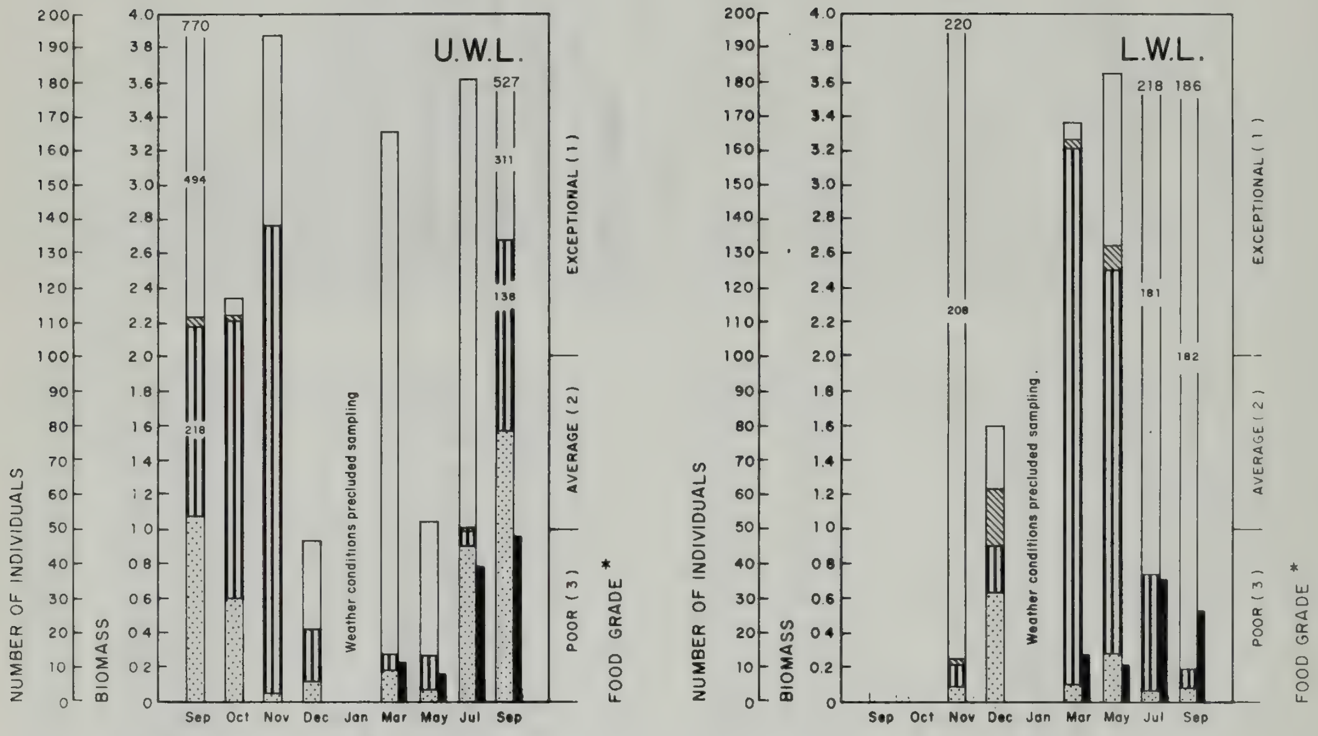


Figure V-29
BENTHIC INVERTEBRATE NUMBERS AND BIOMASS FOR WILLOW CREEK STATIONS SEPT. 1974 - SEPT. 1975

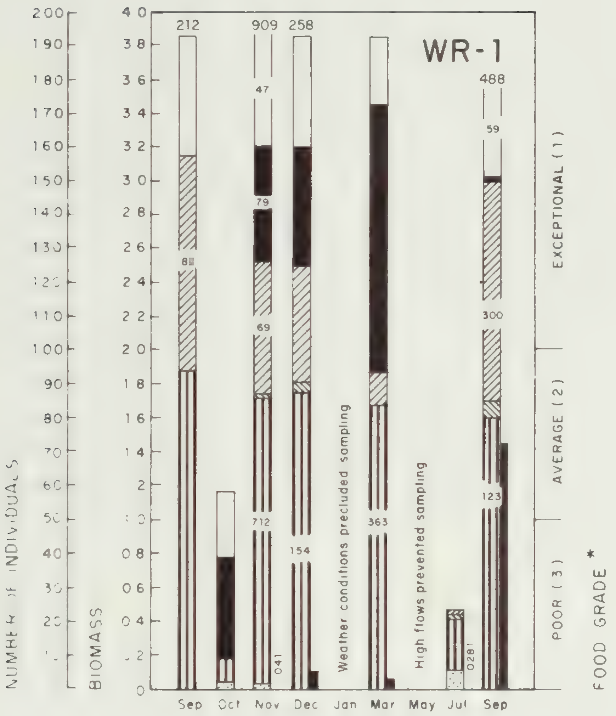


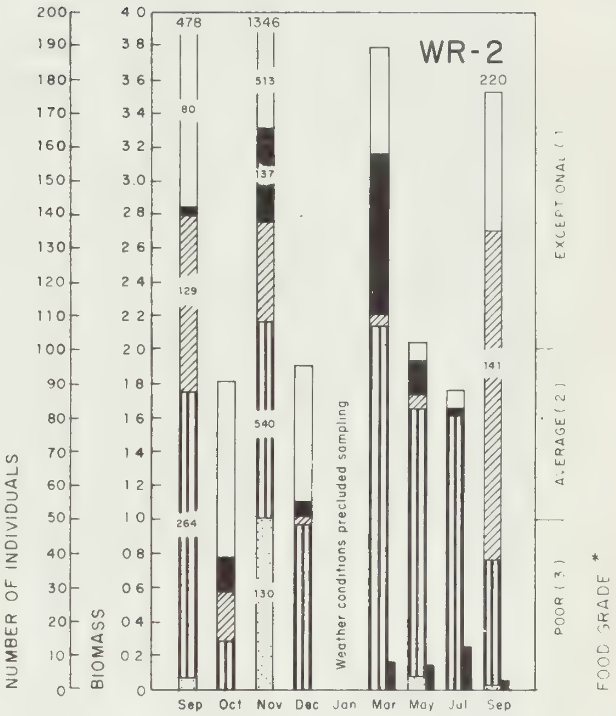
NOTE
* Stream classification based on Lagler, 1956.

= Biomass

Diptera
Plecoptera
Tricoptera
Coleoptera
Ephemeroptera
other

Figure V-30
BENTHIC INVERTEBRATE NUMBERS AND BIOMASS FOR WILLOW LAKES STATIONS SEPT. 1974 - SEPT. 1975





NOTE

* Stream classification based on Lagler, 1956

= Biomass

ptera

Plecoptera

Trichoptera

Coleoptera

Ephemeroptera

other

Figure V-31
BENTHIC INVERTEBRATE NUMBERS AND BIOMASS FOR WHITE RIVER STATIONS SEPT. 1974 - SEPT. 1975

community. It also follows that low diversity may indicate a simple community or one suffering from some environmental perturbation.

Calculated species- diversity indices for all stations are given for the samples collected to date in Tables V-24 through V-27. Although most benthic organisms were not identified to the species level, distinct species within a genera were enumerated which allowed a species-diversity-calculation to be made. Results indicate that the downstream stations in Piceance Creek (P-6 and P-7) are less stable than upstream portions. They may be composed of a simple community or one suffering from environmental perturbations. This is born out by the data collected. Collections at stations P-6 and P-7 are composed primarily of Ephemeroptera, Diptera and Oligochaetes in most months. In addition water quality is degraded at these stations compared to other Piceance Creek stations. Substrate is predominantly silt and mud and fish abundance is low. Gaufin and Tarzwell (1956) found species characteristic of polluted zones also occurred in clear water zones, but in smaller numbers. The lake stations, especially Lower Stewart Lake, have lower species-diversity values. This could be the result of a more uniform habitat than the streams with less opportunity for diversification. MacKay and Kalff (1969) found species diversity was higher during summer and winter than during spring and autumn. This was not the case in the Tract C-b vicinity. Higher values occurred in fall and spring at some stations. Allan (1975) theorized that increased substratum complexity leads to greater species richness. Thorup (1966) found that fauna associated with certain substrates were well defined and that variations dependent on ecological factors other than substrate may occur. The rock substrates at stations P-1 through P-5A, S1-2. W1-3 and WR1-2 offer better conditions for benthic diversity. Because of this, these areas offer better habitat for fish.

c. Periphyton

Periphyton are the assemblage of microscopic plants and invertebrates that cover the substrate within the streams. Periphyton are the most abundant, primary producers in the streams. Periphyton are collected from each station by removing glass slides from the holders which have been immersed in the stream for about a month. Samples are examined in the laboratory for species identification and biomass is determined. Periphyton biomass estimates represent the standing crop or accumulated production over the month-long period that the samples are submerged in the stream.

Algae are the most abundant periphyton, and diatoms are the most abundant algae in the samples taken. Green and bluegreen algae have also been collected. Stations on Willow Creek and the White River generally have the highest, species diversity of periphyton genera. Stations on Piceance Creek near the Tract appear to be similar with regard to species diversity; however, the downstream stations on Piceance Creek appear to have the lower species diversity. Seasonal changes in number of genera collected have been difficult to discern. Some stations show a general increase in numbers while some stations show the opposite trend. The

Table V-24 BENTHIC INVERTEBRATE SPECIES DIVERSITY INDICES FOR PICEANCE CREEK, SEPTEMBER 1974 - NOVEMBER 1975

	Station							
Month	P-1	P-2	P-3	P-4*	P-5	P-5A*	P-6	P-7
September 1974	1.66	2.08	2.59	2.75	3.26	-	1.44	1.00
October	1.49	1.59	2.05	1.36	2.40	-	1.59	1.19
November	2.21	1.40	2.47	2.46	2.20	1.29	0.44	1.42
December	0.67	1.47	2.37	-	2.12	1.16	2.02	1.84
January 1975	1.76	1.82	1.58	-	2.35	1.06	1.27	1.76
March	1.75	1.77	1.65	-	2.24	2.08	1.16	1.49
May	1.62	1.99	2.00	-	1.65	2.80	1.44	0.97
July	1.74	1.76	2.01	-	1.84	1.61	1.82	0.86
September	2.31	2.40	1.96	-	2.18	1.55	1.33	1.52
November	1.55	1.10	2.86	-	2.65	0.84	0.70	0.35

*Station P-4 was relocated to P-5A in November 1974.

Table V-25 BENTHIC INVERTEBRATE SPECIES DIVERSITY INDICES FOR STEWART CREEK AND LAKES, SEPTEMBER 1974 - NOVEMBER 1975

	Station			
Month	S-1	S-2	USL	LSL
September 1974	1.65	2.00	1.95	0.41
October	2.43	2.10	0.58	1.40
November	2.02	2.44	0.51	0.49
December	1.98	2.34	*	0.54
January 1975	**	2.24	*	**
March	2.34	2.65	*	0.56
May	2.52	1.27	0.96	1.48
July	2.74	2.51	1.96	0.67
September	1.82	1.43	1.81	0.50
November	2.29	2.20	1.90	0.40

* Station was frozen over.

** Weather conditions precluded taking samples.

Table V-26 BENTHIC INVERTEBRATE SPECIES DIVERSITY INDICES FOR WILLOW CREEK AND WILLOW LAKES, SEPTEMBER 1974 - NOVEMBER 1975.

	Station				
Month	W-1	W-2	W-3	UWL	LWL
September 1974	1.95	3.29	1.22	1.34	***
October	2.19	2.31	1.74	1.33	***
November	2.64	2.45	2.99	0.87	0.38
December	3.02	2.65	1.87	1.46	1.99
January 1975	*	*	2.34	**	**
March	1.39	0.50	1.55	0.68	0.50
May	1.64	2.63	1.46	1.39	1.41
July	1.17	1.05	1.23	1.20	0.76
September	2.34	1.18	2.38	1.57	0.34
November	2.48	2.28	2.35	0.93	2.26

* Stations were frozen over.

** Weather conditions precluded taking samples.

*** Station LWL sampling started in November 1974

Table V-27 BENTHIC INVERTEBRATE SPECIES DIVERSITY INDICES FOR THE WHITE RIVER, SEPTEMBER 1974 - NOVEMBER 1975

Month	Station WR-1	Station WR-2
September 1974	1.79	1.79
October	1.83	1.75
November	2.88	2.82
December	2.02	2.88
January 1975	*	*
March	1.84	2.21
May	**	2.10
July	2.13	0.55
September	2.22	1.74
November	**	2.12

* Stations were frozen over.

** Unable to sample.

greatest number of genera collected in any month appeared in Willow Creek. The least number of genera collected occurred at the downstream Piceance Creek station.

Piceance Creek stations appear to have the greatest periphyton biomass (dry weight) per unit area. The highest estimate was 84 grams per square meter in Piceance Creek while the lowest estimate was 0.62 grams per square meter in Stewart Creek. Seasonal changes are quite evident. Eight of the twelve stations sampled showed decreased biomass estimates as winter approached. The seasonal decrease was especially evident along Piceance Creek. In general the greatest number of species did not correspond with the greatest estimate of biomass. Data indicate that Piceance Creek, although slightly lower in species diversity, has the greatest estimates of periphyton biomass. Willow Creek and the White River are similar in the estimates of periphyton biomass while Stewart Creek has been the least productive. Periphyton productivity estimates ranged from 0.0022 to 2.0297 gm. ash-free-dry-wt./m^2/day in Piceance Creek stations. The highest productivity has occurred in the middle portions of the sampling area (Stations P-3 through P-5A), while the lowest productivity has occurred at the downstream stations (P-6 and P-7). In Stewart Creek periphyton productivity ranged from 0.0023 to 0.1417 gm. ash-free-dry-wt./m^2/day.

The herbivorous-fish species appear to thrive in Piceance Creek. Periphyton production coupled with abundant growth of Cladophora sp. in summer apparently provides adequate food. Cladophora growth is abundant in summer in the White River and rocky areas of Piceance Creek. Watercress is abundant in Stewart and Willow Creeks.

d. Primary Productivity

Light-and-dark bottle, dissolved-oxygen determinations have been conducted in the lake to assess phytoplankton primary productivity. Results to date have been inconclusive. Dissolved oxygen values in the lake and the light-and-dark bottle values have all been similar. No significant decrease in dissolved oxygen was detected in the dark bottles after 24-hour incubation. This could be the result of light inhibition because of the clarity of the lake waters. An effort was made to incubate bottles at deeper depths to overcome this problem. However, the shallowness of some of the lakes and their fluctuating levels have precluded placing samples deeper in the lakes.

e. Water Quality

Water quality samples are collected at 14 streams and lake stations along Piceance, Stewart and Willow Creeks in the vicinity of the Tract and at two stations along the White River. Analyses on all samples have been conducted for 31 parameters, as shown on example Table V-28. Complete data have been reported in Quarterly Data Report #5. Sediment analyses were begun in May 1975. Analyses are also conducted on four characteristics of sediment.

Table V-28 MONTHLY WATER QUALITY SAMPLE ANALYSES FOR PICEANCE CREEK STATIONS

STATION: P-1

Note ND = Not Detected

CONSTITUENTS	1974 Aug	1974 Sep	1974 Oct	1974 Nov	1974 Dec	1975 Jan	1975 Mar	1975 May	1975 Jul	1975 Sep	1975 Nov	1976 Jan	1976 Mar	1976 May	1976 Jul
Temperature (°F)	61.0°	56.0°	54.0°	39.2°	32.0°	Frozen	43.0°	46.0°	58.1°	46.4°	34.0°				
pH	8.2	8.4	8.3	8.1	8.2	Over	8.3	8.4	8.3	8.5	8.3				
Dissolved Oxygen (mg/l)	7.0	10.0	11.0	14.9	15.0		15.0	10.5	10.9	15.0	14.5				
Conductivity (μ ohms/cm)	1075	1125	1200	1200	1280		1200	920	1300	1300	1300				
Total Solids (ppm)	636	716	920	888	728		916	600	770	700	708				
Total Alkalinity ($CaCO_3$)(ppm)	320	410	430	390	445		440	370	475	460	435				
Total Hardness ($CaCO_3$)(ppm)	260	310	330	290	350		320	291	345	360	400				
CATIONS (ppm)															
Calcium (Ca)	22	66	52	52	76		60	60	72	74	82				
Magnesium (Mg)	50	35	49	39	39		41	34	40	43	67				
Sodium (Na)	120	138	140	148	128		128	75	144	124	116				
Potassium (K)	2.8	1.9	3.1	2.5	2.5		2.8	1.7	5.0	4.0	3.8				
Ammonia (NH_4)	0.89	0	0	0.1	0		0.48	0.06	0.59	0.03	0.54				
ANIONS (ppm)															
Hydroxide (OH)	0	0	0	0	0		0	0	0	0	0				
Carbonate (CO_3)	24	12	6	18	0		0	0	24	12	12				
Bicarbonate (HCO_3)	342	476	512	439	543		537	451	531	537	506				
Sulfate (SO_4)	166	155	165	152	160		145	83	144	162	167				
Chloride (Cl)	25	17	20	25	20		15	8.0	15	4.0	16.0				
Nitrate (NO_3)	1.4	0.35	0.13	1.6	1.4		0.98	4.4	0.93	1.8	2.0				
Boron (B)	0.38	0.18	0.17	0.25	0.18		0.26	2.4	0.20	0.27	0.36				
Silica (SiO_2)	16	14	17	18	18		17	12	18	17	17				
Iron (Fe)	0.74	0.83	0.43	1.1	1.3		0.48	29	1.3	0.63	1.2				
Manganese (Mn)	0	0	0	0	0		0	0	0	0	0				
NUTRIENTS (ppm)															
Ortho Phosphate (PO_4)	0.04	0.08	0.05	0.07	0.00		0.08	0.00	0.04	0.07	0				
Nitrite (N)	0	0.001	0	0	0		0	0	0	0.014	0.010				
Nitrate (N)	0.31	0.08	0.003	0.36	0.31		0.22	0.99	0.21	0.40	0.44				
Ammonia (N)	0.69	0	0	0.08	0		0.37	0.05	0.46	0.02	0.42				
MICROBIOLOGY															
Standard Plate Count/ml at 35°C	840	1000	210,000	280,000	170,000		50,000	11,000	130,000	2,300	3,700				
Coliform MPN/100 ml	4600	43	110	23	1100		1100	>24,000	4600	1,500	4,600				
Fecal Coliform MPN/100 ml	43	9	<3	4	23		23	2400	460	460	46				
Fecal Streptococci MPN/100 ml	-	< 3	93	43	43		280	< 3	240	240	< 3				
Pathogens	-	ND	ND	ND	ND		ND	ND	ND	ND	ND				
SEDIMENT ANALYSIS															
% Moisture								21.6		33.9					
% TKN								0.027	0.023	0.11					
% COD								0.49	0.63	2.9					
% Volatile Solids								1.7		5.4					

The total dissolved solids in streams in the vicinity of the Tract is high (about 800 to 1000 ppm) which is characteristic of other streams in the Piceance Basin.

Station P-7, located about eight miles downstream from the Tract, has a total dissolved solids content slightly higher than nearer the Tract, ranging from 1000 to 1500 ppm. The water quality in the White River is better than that in Piceance Creek ranging from 200 to 500 ppm of total dissolved solids. Total dissolved solids for the streams studied fluctuate seasonally with low levels occurring during periods of high flow as shown in Figures V-32 to V-35. The high dissolved solids, along with the high turbidity at times from siltation, results in a habitat of marginal quality.

Water temperatures fluctuate from freezing levels in winter to temperatures around 60°F in summer as shown in Figures V-36 through V-39. Dissolved oxygen levels (also shown in Figures V-36 through V-39) are adequate year round to support aquatic life. Coliform levels in the streams in the vicinity of the Tract exceed state water-quality standards at certain times of the year. These high coliform levels coincide with intensive cattle and sheep grazing along the streams and with the return of irrigation water to the streams. All of the streams tested are alkaline (pH generally greater than eight). A general degradation of water quality of the streams near the Tract occurs in the downstream direction. Sulfate levels are high in the streams of the Piceance Basin.

Sediment analyses have yielded no unusual values for the parameters tested. Heavy metal concentrations were within acceptable limits.

f. Springs and Seeps

A total of 12 springs and seeps in the Tract vicinity have been enumerated to date. Locations of identified springs and seeps are listed below:

Piceance Springs

Spring 1 - Seepage along eastern edge of Lower Stewart Lake (L.S.L.). No vegetation. Substrate of small shingle. Lake itself is sampled by aquatic team.

Spring 2 - Spring at Savage Cabin, Stewart Gulch. Four main sources which converge and flow into Middle Stewart Gulch. Choked with water cress (*Nasturtium officinale*).

Spring 3 - Spring issuing from concrete structure against hillside at mouth of Stewart Gulch. Behind ranch house. Water cress present.

Spring 4 - Seep forming marsh at mouth of East Stewart Gulch. Rushes (*Carex*). Not sampled since no pool or stream channel present.

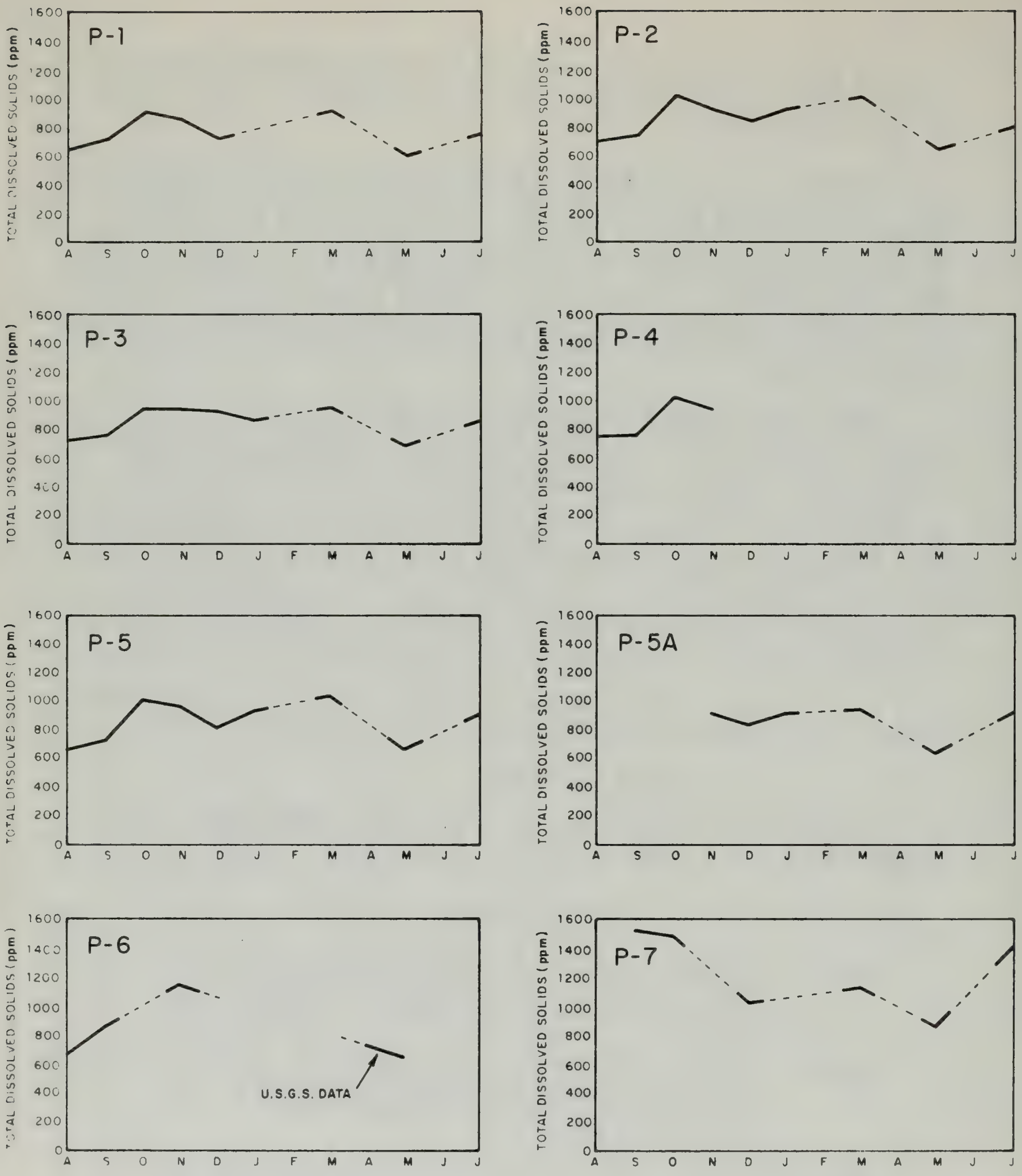


Figure V-32
TOTAL DISSOLVED SOLIDS AT THE PICEANCE CREEK STATIONS, AUGUST 1974 TO JULY 1975

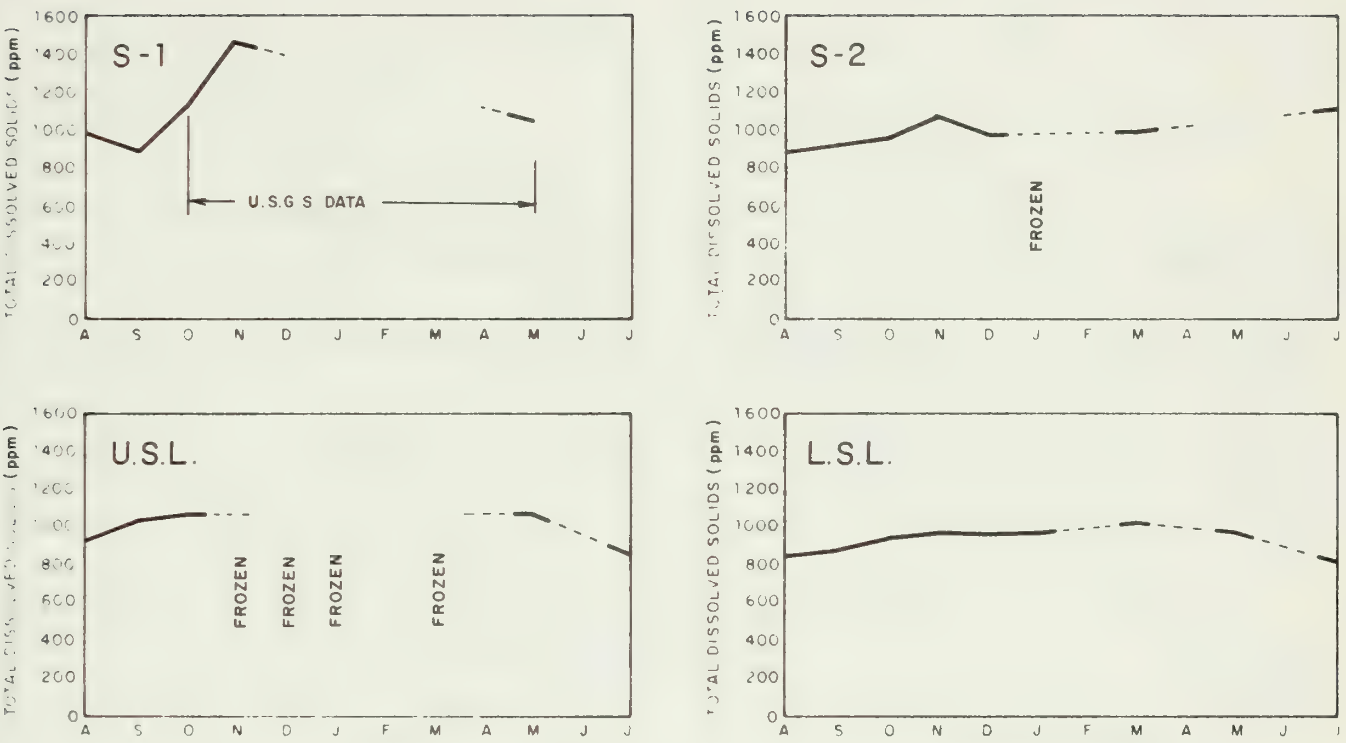


Figure V-33
TOTAL DISSOLVED SOLIDS AT THE STEWART CREEK STATIONS,
AUGUST 1974 TO JULY 1975

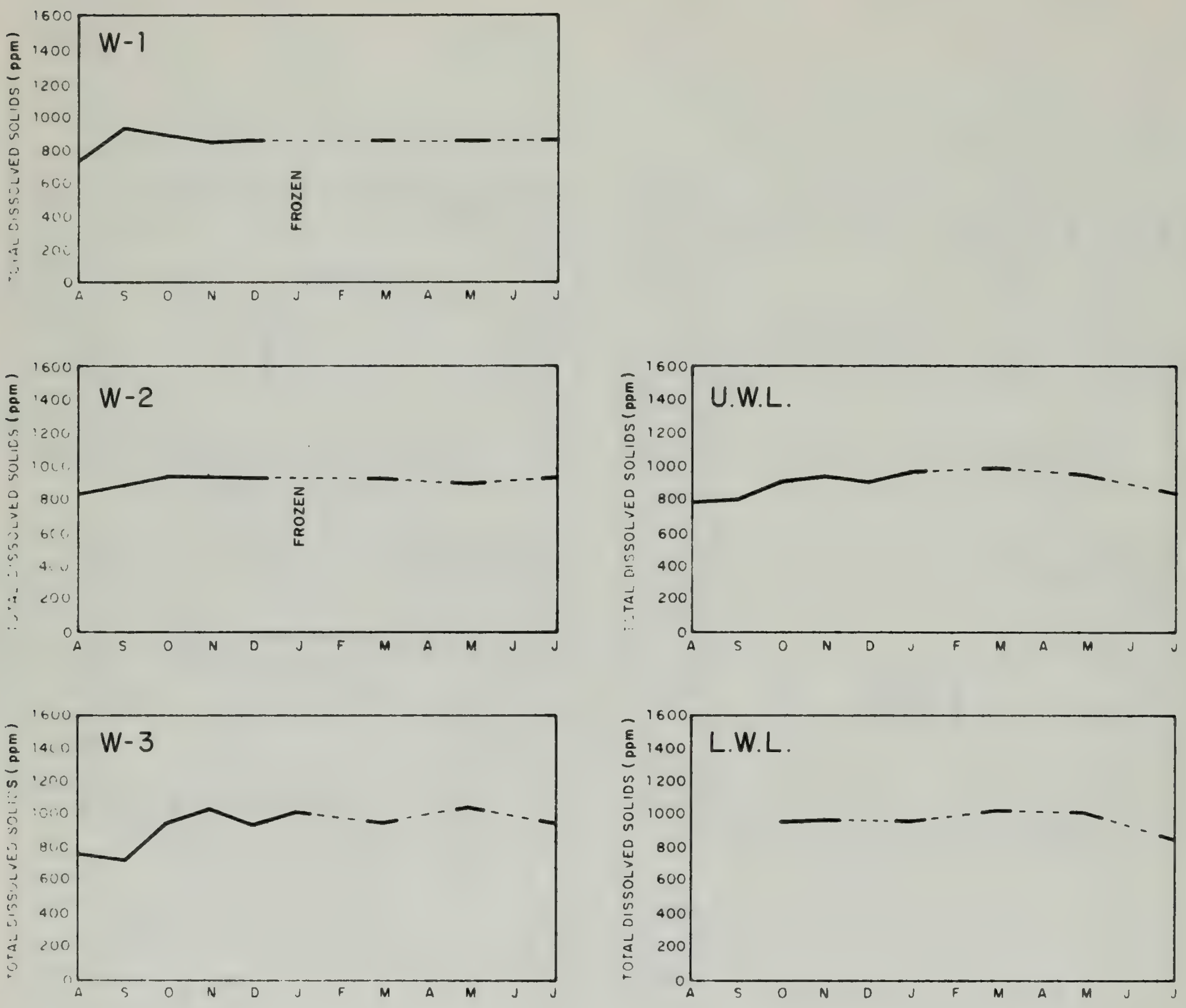


Figure V-34
TOTAL DISSOLVED SOLIDS AT THE WILLOW CREEK STATIONS, AUGUST 1974 TO JULY 1975

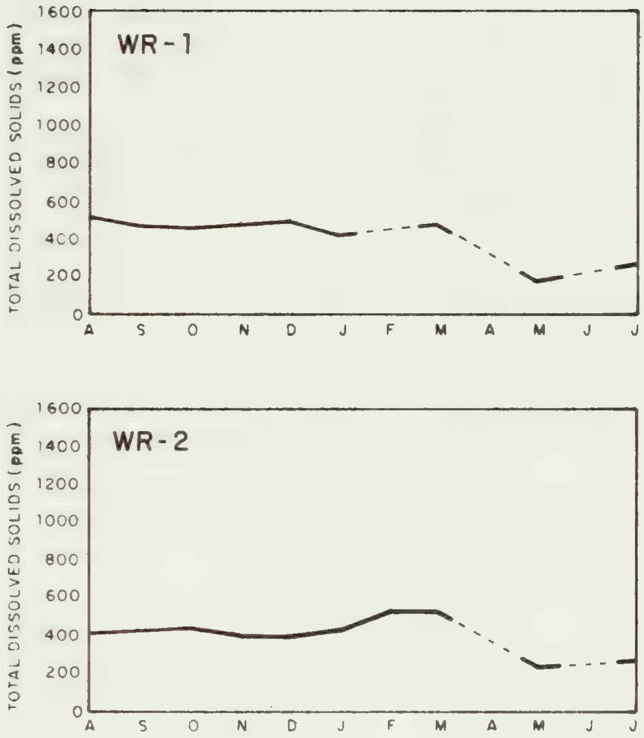


Figure V-35
TOTAL DISSOLVED SOLIDS AT THE WHITE RIVER STATIONS, AUGUST 1974 TO JULY 1975

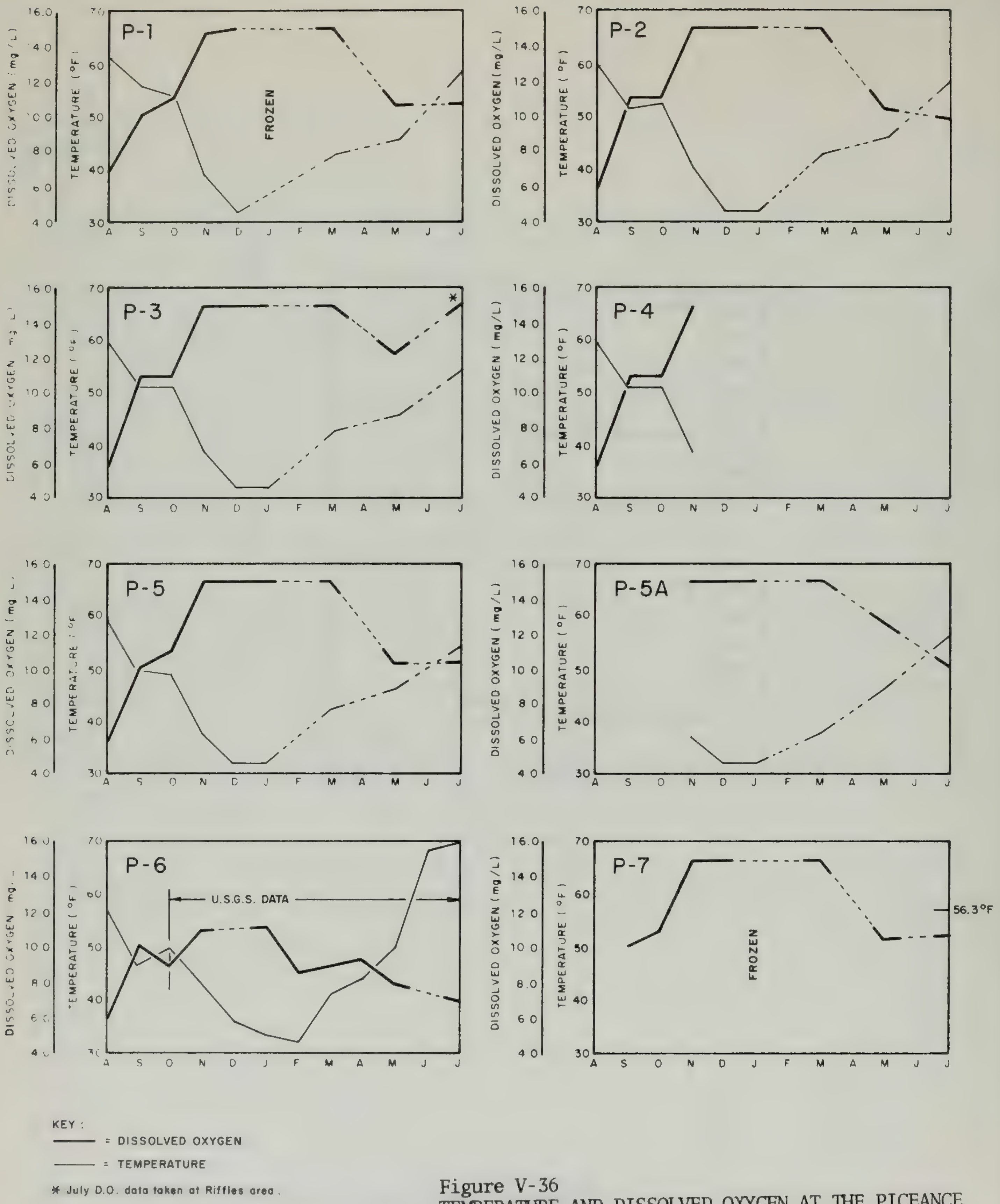


Figure V-36
TEMPERATURE AND DISSOLVED OXYGEN AT THE PICEANCE CREEK STATIONS, AUGUST 1974 TO JULY 1975

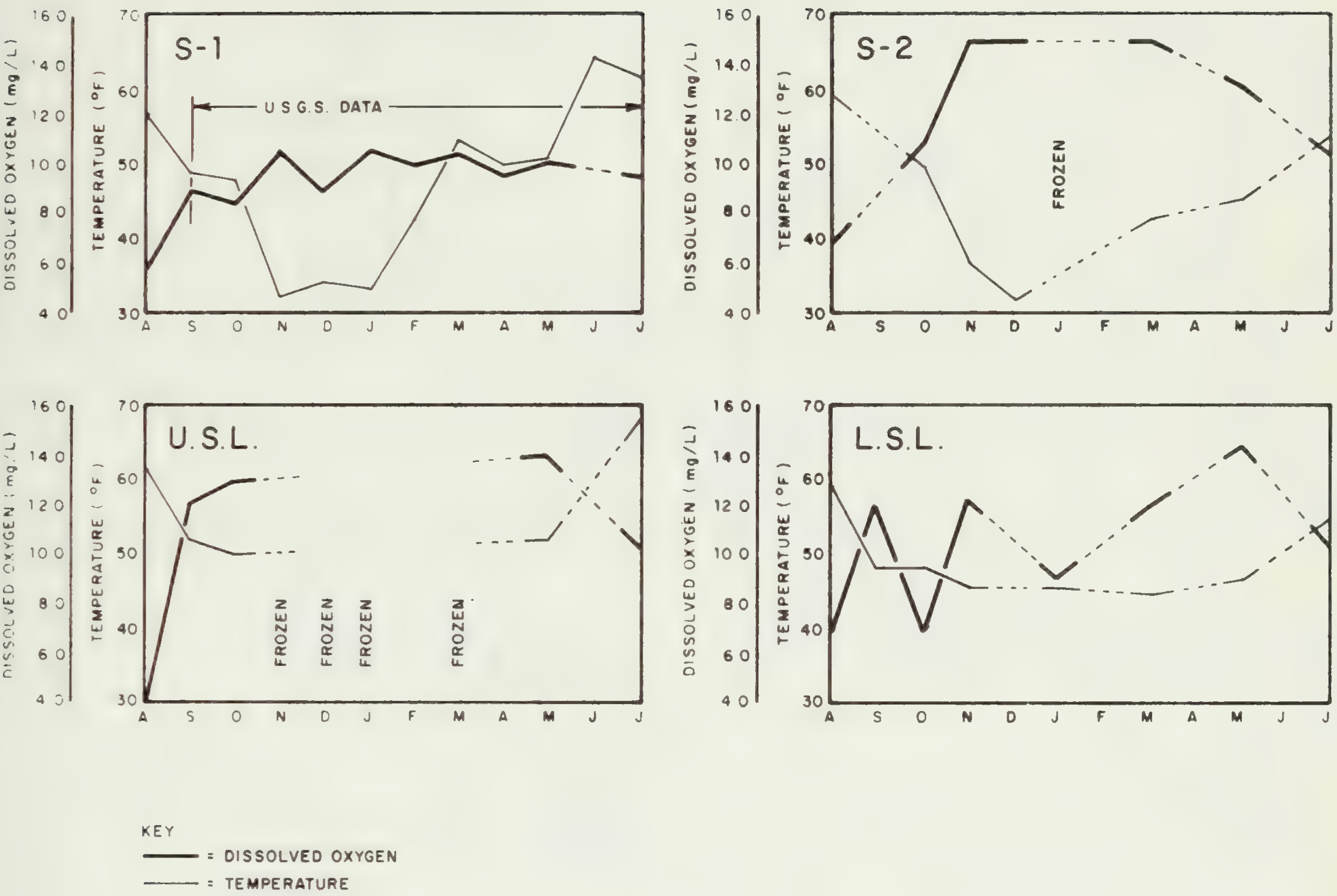


Figure V-37
TEMPERATURE AND DISSOLVED OXYGEN AT THE STEWART CREEK STATIONS, AUGUST 1974 TO JULY 1975

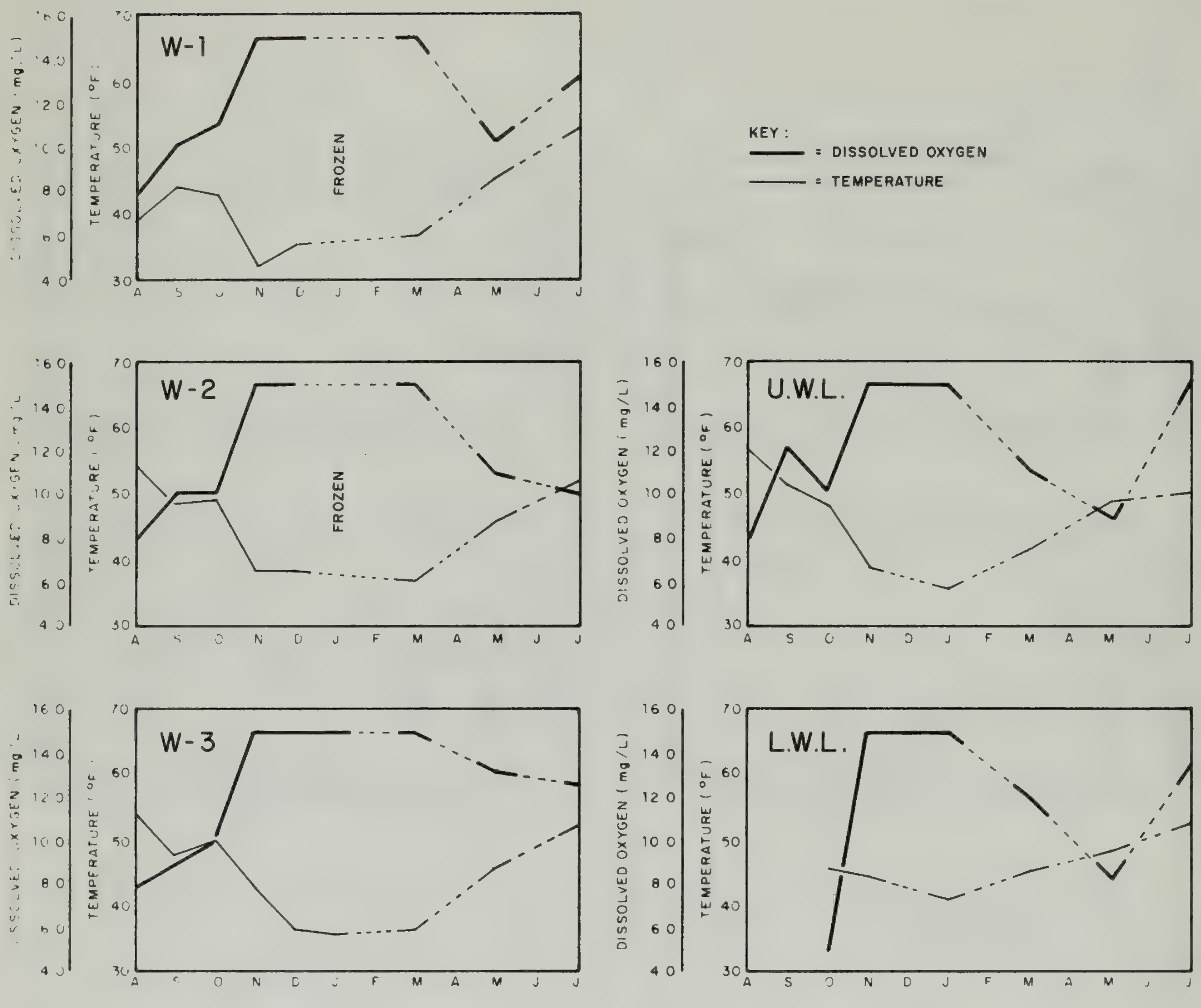


Figure V-38
TEMPERATURE AND DISSOLVED OXYGEN AT THE WILLOW CREEK STATIONS, AUGUST 1974 TO JULY 1975

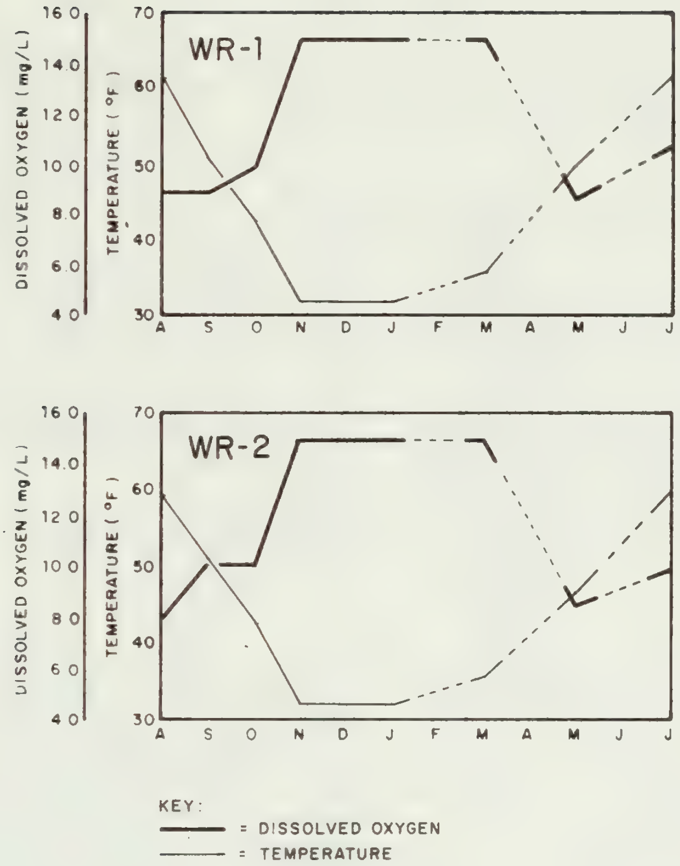


Figure V-39
TEMPERATURE AND DISSOLVED OXYGEN AT THE WHITE RIVER STATIONS, AUGUST 1974 TO JULY 1975

Spring 5 - Spring issuing from concrete structure behind Oldland ranch house. A few meters from Spring 3. Similar to Spring 3.

Spring 6 - Spring at mouth of Willow Creek west of PL Ranch. Issues from hillside above pond NW of ranch house. Gravel substrate.

Spring 7 - Spring at PL Ranch. Choked with water cress.

Spring 8 - Spring at Willow Creek at mouth of Scandard Gulch. Gravel bottom at source - water cress appears about two meters from source.

Spring 9 - Limnocrene along Willow Creek. Sampled by aquatic team as Upper Willow Lake (U.W.L.).

Spring 10 - Willow Creek two miles south of Scandard Gulch. Flows few meters into Upper Willow Lake. Much water cress.

Spring 11 - Seep forming a *Carex* marsh southeast of Savage Cabin, Stewart Gulch. Not sampled since no well-defined channel or pool.

Spring 12 - Seep immediately to the southeast of Spring 11. Similar to Spring 11. Not sampled.

Springs and seeps in the Piceance Basin were examined in March and July of 1975. Aquatic macroinvertebrates were collected from nine locations. Three locations were not sampled since their sources were diffuse and formed marshy areas without pools or well-defined channels. Temperature and dissolved oxygen (July only) data were also gathered. They were similar to data gathered from aquatic sampling stations. Macroinvertebrates identified were the result of qualitative hand collection. The majority of macroinvertebrates identified from springs are also identified from aquatic sampling stations. Species lists and water quality data have been reported in *Quarterly Data Report #5*.

4. Aquatic Ecosystem

The aquatic ecosystem in the streams of the Piceance Creek Basin includes interactions between the various organisms studied during the baseline program and others which aid in recycling materials between the living and nonliving portions of the system. Figure V-40 gives a simple visual picture of the basic components of the stream ecosystem and streamside vegetation in the Tract C-b vicinity.

Aquatic communities characteristically undergo seasonal changes in species' composition and abundance, as well as changes over a period of

Figure V-40. Major Stream Organisms and Representative Streamside Vegetation in Tract C-b Vicinity

74-669

years. This is a natural phenomenon. The food web involves the transfer of energy from plants through a series of organisms (Figure V-41). The periphyton of the streams are the major primary producers which convert basic materials into organic substances through photosynthesis. The periphyton are associated with submerged surfaces and include bacteria, algae, protozoans and other microscopic animals and often early stages of organisms that grow to become part of the benthos. The benthos are the plants and animals living on or in the stream bottom. In the streams the majority of these are primarily aquatic insects and larvae. The herbivores feed on the plant material. The aquatic insects and some fish species (mountain sucker, speckled dace) are the major herbivores in the stream. The carnivores feed on the herbivores. The brook trout is the major carnivore in the streams on the Tract. They feed primarily on insects.

The diversion of stream water for irrigation purposes has a pronounced effect on stream flow rates during summer months in the vicinity of Tract C-b. Cattle grazing during winter and spring in the meadows bordering streams affects water quality. Turbidity is a problem in Piceance Creek during periods of high runoff (spring).

Quantitative measurements have been made for fish populations, periphyton productivity, benthic-invertebrate biomass and abundance, species-diversity and water quality parameters. Figure V-42 shows the major interactions with quantitative data for the components being studied.

Material from the various levels is eventually decomposed and converted to nutrients for use by plants and periphyton for photosynthesis. There can be interconnected sequences of conversion as well as simple, isolated interactions. A further discussion of the ecosystem interactions is found in Chapter VII.

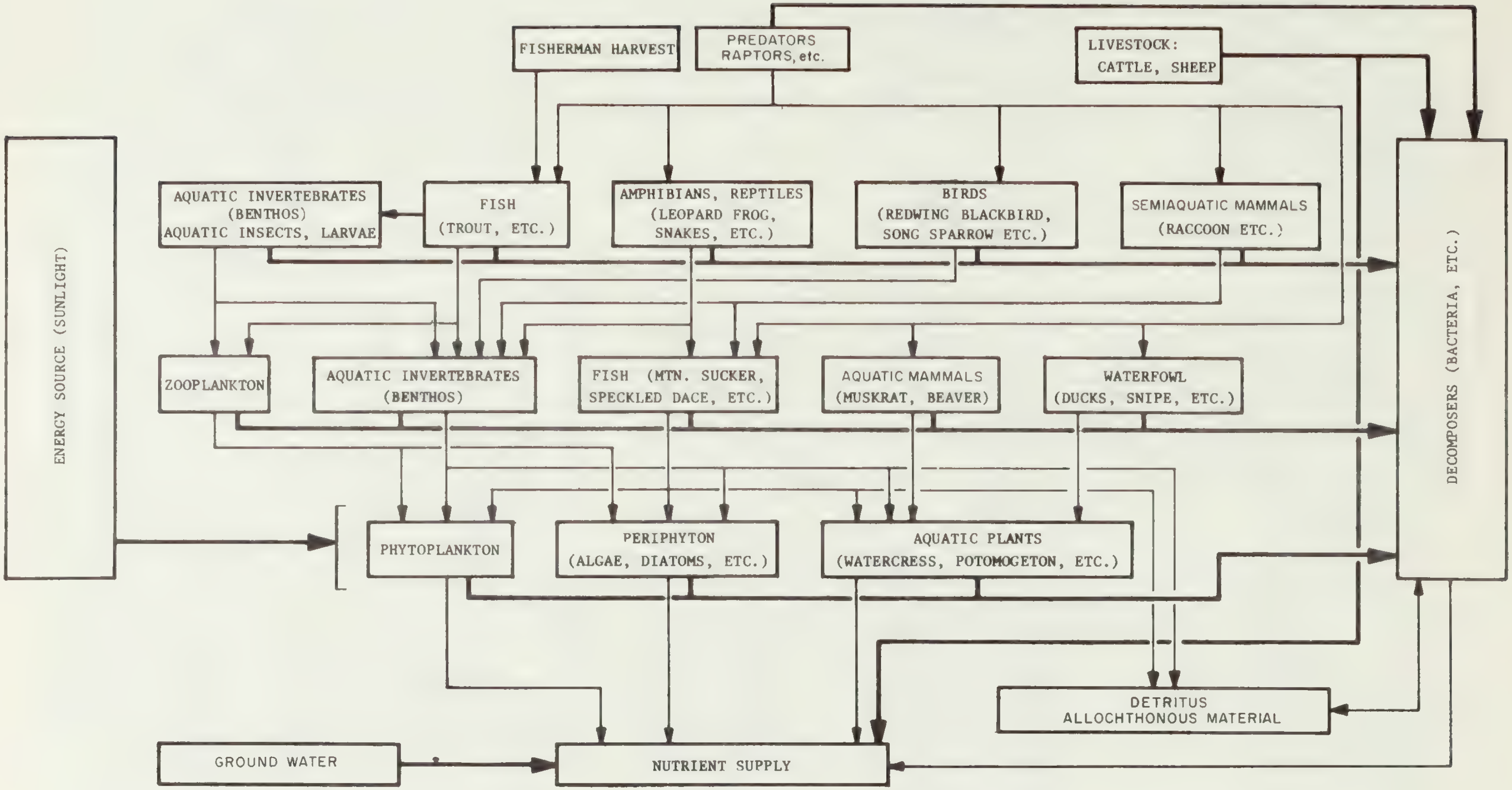


Figure V-41. Generalized Interactions for the Aquatic Ecosystem in the Tract C-b Vicinity

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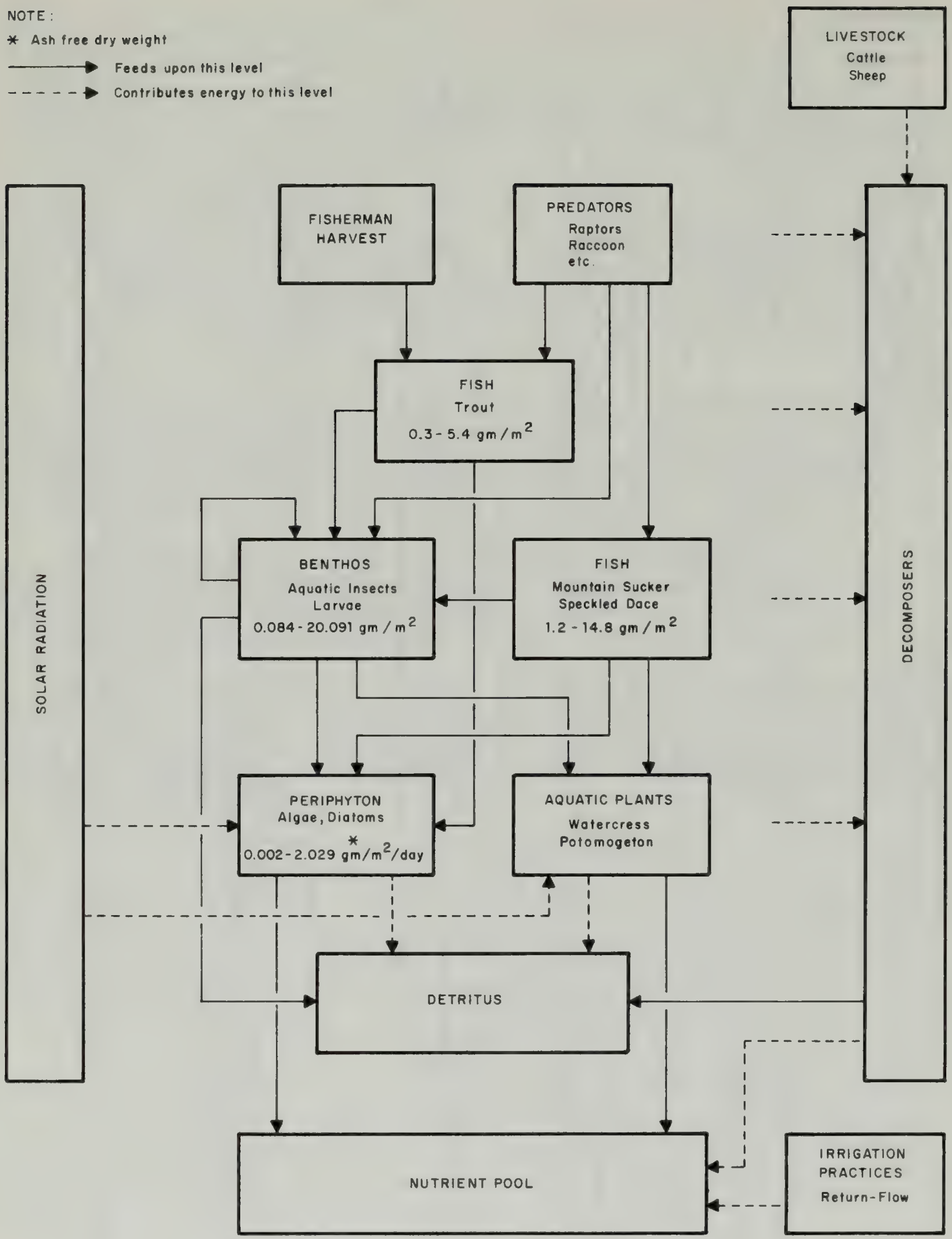


Figure V-42. Major Interactions and Productivity and/or Biomass Estimates for the parameters being studied in the Tract C-b Aquatic Ecosystem

G. Plant Communities and Dynamics

1. Introduction

The study of vegetation on Tract C-b during the first year of baseline investigation has focused on meeting the requirements outlined in the Federal Oil Shale Lease, and also on providing a base from which a meaningful, monitoring program can be developed. Much of the rationale for experimental design has been reported elsewhere (Quarterly Data Reports #1 - 4) and will not be repeated here. Update and review of some methodology, however, is appropriate and some material is presented for the first time in this report.

2. Methods and Statistical Testing

a. Floristic Studies

Tract flora have been identified via a list of species observed during the course of other vegetation studies. Collections of species have been made to provide a reference set of specimens. Floristic analyses of Raunkiaerian life form and geographic affinity have been made for the species which occur on the site. Nomenclature follows Harrington (1964) and in those cases where nomenclatural changes have occurred, Weber (1972) has been used to provide the more-correct name.

b. Vegetation Mapping

The vegetation map of the study area has been prepared at a scale of 1:12,000 using a modification of Kuchler's comprehensive method (Kuchler, 1967). This approach utilizes a combination of air-photo interpretation and on-the-ground field checking. The final map is prepared by transferring information from the photographs to a topographic base map.

c. Vegetation Sampling Program

Two different approaches to the sampling of plant communities on Tract C-b have been utilized. The first centers on six intensive study sites located in the major plant communities on the Tract (pinyon-juniper-woodland, chained-rangeland, upland-sagebrush and bottomland-sagebrush communities). Included at these sites are permanently located herb quadrats, shrub transects (Lindsey, 1955) and marked trees in the woodland sites. Observations at these sites over time will allow for determination of structural changes in these plant communities. The second sampling approach is designed to provide descriptive data for the less-common plant communities on the Tract. Stands of homogeneous vegetation are selected and sampled by the same methods utilized at the intensive study plots. However, the area is sampled only once and no permanent transects or quadrats are established. Additional stands of the major vegetation types have also been sampled in this manner to assess the kinds and amounts of variation which occur in these communities and also to evaluate representativeness of the intensive study sites.

Two different approaches have been used to evaluate the adequacy of the phytosociological samples. Not every stand has been analyzed; however, those which have been tested show that enough samples have been taken to estimate total shrub density, tree density and herb frequency. The assumption has been made for trees and shrubs that, if density estimates are adequate, estimates of other phytosociological parameters are also adequate. The adequacy of the herb sample has been evaluated using a species-area curve. For stand 12, a pinyon-juniper woodland, (Figure V-43), the total number of species encountered reached a maximum after 14 one-square meter quadrats had been sampled. The graph suggests that further sampling of this stand would provide limited additional information about herb-layer species composition. The pinyon-juniper woodlands are intermediate to the chained rangelands and sagebrush communities in terms of herb-layer diversity. Fewer quadrats would be required for adequate sampling in the sagebrush communities and more would be required in chained rangelands. A total sample of 20 quadrats per stand has proved to be a very useful number both in terms of adequacy of sample and time required for data collection.

Adequacy of shrub-density estimates are based on total density rather than on estimates for individual species since the adequacy diminishes as species become less common. Sample adequacy has been evaluated by calculation of the ratio of the standard error of the mean to the mean expressed as a percent (Grieg-Smith 1964). An arbitrarily established standard of 10% for this value has been used in plant ecology as a suitable level for an adequate sample (F. Glenn Goff personal communication, Oak Ridge National Laboratory). The value of this ratio for shrub density data in stand 12 is 10.1%. In other sampled stands this value approaches 5% and in those communities where shrubs are less common, e.g., bunchgrass, the value is greater than 10%. Density estimates are based on 20 shrub transects for each stand; and, based on evaluations, suitable estimates are obtained for the sampled communities.

Evaluation of tree density data has also been conducted using the standard error of the mean value to mean value ratio. The measurement which has been used for testing of the trees is the quarter-distance method from each point to each tree (Cottam and Curtis 1956). A total of 160 distances from 40 points has been used to sample each woodland stand. The ratio value for stand-12 distances was 4.4%. This indicates a more-than-adequate sample size.

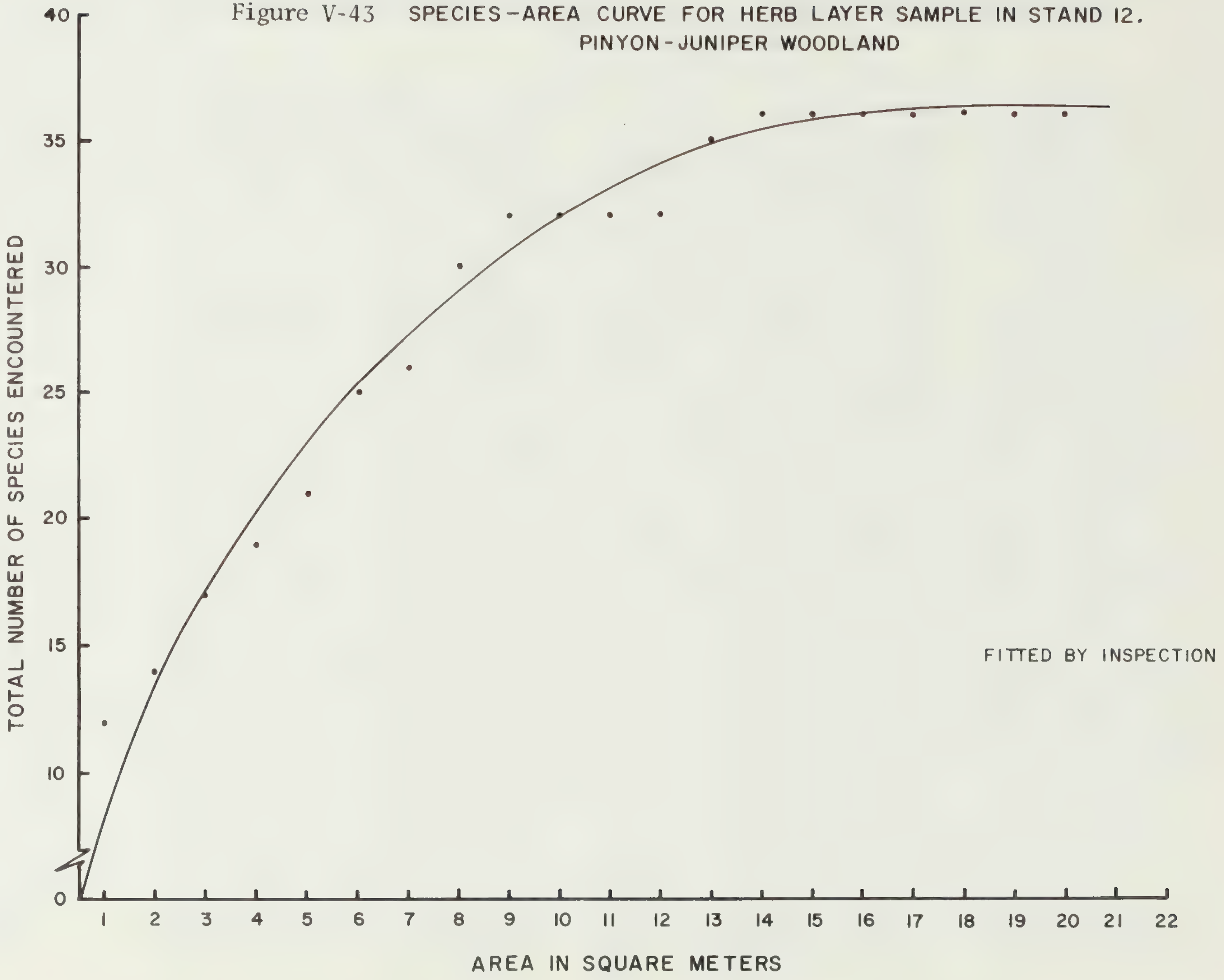
Stand 12 was selected for the above illustrations because herb, shrub and tree data were available for evaluation. Other stands show comparable values which suggest that sample sizes for estimating phytosociological parameters are adequate.

d. Production Studies

(i) Herb Production

Herb production estimates have been determined by monthly clippings (May-August) of 10, $0.1m^2$ quadrats in each plot at the intensive study

Figure V-43 SPECIES-AREA CURVE FOR HERB LAYER SAMPLE IN STAND 12. PINYON-JUNIPER WOODLAND



sites. The clipped sample was divided into three fractions: current live material, stacking and attached dead, and litter and prostrate dead. This separation allows for estimation of growth rate, rate of litter disappearance and mortality, all of which will be used in determination of net shoot primary productivity (Odum 1960, Ovington, et. al., 1963, Wiegert and Evans, 1964). In addition to the clippings in the open and deer-fenced exclosure a clip sample was also made from a contiguous barbed-wire fenced plot. The total number of quadrats at each site for each date was thirty. Because of the apparent lack of differences among the individual 10-quadrat samples, the clipping data have been combined so that estimates given in this report (Table V-29a) are based on a total sample of thirty clip plots per site per date.

Evaluation of the adequacy of herb-clipping sample size is more difficult than for phytosociological data. The same value (standard-error-of-the-mean-to-mean ratio ($S_{\bar{y}}/\bar{y}$) expressed as a percent) has been used to evaluate the adequacy of the data. Because of the inherent variation in the herb layers of different vegetation types, different levels of adequacy exist. The upland sagebrush community (Plot 3) is characterized by a rather homogeneous herb layer composed mostly of rhizomatous grasses and small forbs. The even distribution of these species within the herb layer is an important factor governing the variation encountered in the clip plot samples. Examination of summarized data for combined plot 3 data from July (Table V-29a) shows that 15, 0.1m^2 quadrats were necessary to obtain 10% standard error of the mean-mean ratio. Additional samples reduce the ratio value only slightly as sample size increases.

Clip data from July for Plot 1 demonstrate a very different pattern (Table V-29b). The herb layer in the chained rangeland community is characterized by bunchgrasses which, because of their growth, form a discontinuous distribution of individuals. Variance (S^2) increases as both clump and interclump areas are encountered in the clip samples. Even with a sample size of 30 plots the standard error of the mean-mean ratio is nearly 30%. High variance within these samples suggests that for future data collection an increase in both number of samples and quadrat size may be appropriate.

The examples from Plot 3 and Plot 1 were selected as extremes in the sampling data. The data from Plot 3 represent one of the most internally consistent data sets while the data from Plot 1 show some of the greatest internal variation. Sample variances in the early-growing season are more consistent since disparities in the clump and interclump estimates in the chained rangelands are not as great.

(ii) Shrub Production

Estimates of shrub production have been made on an individual shrub basis rather than the areal estimate utilized for herbs. Samples of entire stems from eight shrub species were collected in April and September. The total number of stems growing from the base of the plant was recorded and used to estimate the total plant dry weight based on the dry weight of the cut stem. Average dry weight per plant values were multiplied by shrub density estimates for each species to derive a shrub standing-

Table V-29a. Statistical Summary of Herb Clipping Data From Site 3, July 1975. Values Are Grams Per $0.1m^2$.

Table V-29b. Statistical Summary of Herb Clipping Data From Site 1, July 1975. Values Are Grams Per $0.1m^2$.

		PLOT 3 JULY					PLOT 1 JULY				
	Number of Samples	$\bar{y}$	S^2	S	$S\bar{y}$	$S\bar{y}$ as % of $\bar{y}$	$\bar{y}$	S^2	S	$S\bar{y}$	$S\bar{y}$ as % of $\bar{y}$
CATTLE EXCLOSURE	1										
	2	3.4909	0.0247	0.2224	0.1573	4.5	2.072	4.293	2.930	2.072	100
	3	4.1532	0.8939	1.158	0.668	16.1	2.445	3.140	2.170	1.253	51.3
	4	4.746	1.726	1.517	0.758	15.9	1.834	3.476	2.153	1.076	58.7
	5	4.208	2.539	1.781	0.797	18.9	10.920	333.026	20.403	9.124	83.6
	6	4.868	4.291	2.269	0.926	19.0	9.100	294.084	18.786	7.669	84.3
	7	5.128	4.082	2.182	0.825	16.1	12.541	323.130	19.416	7.339	58.5
	8	5.565	4.913	2.370	0.838	15.0	11.047	298.360	18.466	6.529	59.1
	9	5.263	5.097	2.395	0.798	15.2	10.792	265.730	17.290	5.763	53.4
	10	5.420	4.809	2.312	0.731	13.5	10.061	243.975	16.465	5.207	51.8
DEER EXCLOSURE	11	5.440	4.376	2.194	0.662	12.2	9.658	223.419	15.677	4.727	48.9
	12	5.306	4.209	2.143	0.619	11.7	9.456	205.247	14.963	4.320	45.7
	13	5.407	4.007	2.084	0.578	10.7	9.417	189.478	14.327	3.974	42.2
	14	5.302	3.864	2.040	0.545	10.3	9.210	176.497	13.787	3.685	40.0
	15	5.323	3.613	1.968	0.508	9.5	8.885	166.214	13.345	3.446	38.8
	16	5.297	3.398	1.904	0.476	9.0	8.394	159.442	13.041	3.260	38.8
	17	5.375	3.298	1.872	0.454	8.4	7.900	153.964	12.790	3.102	39.3
	18	5.669	4.584	2.203	0.519	9.2	8.095	146.057	12.436	2.931	36.2
	19	5.641	4.358	2.146	0.492	8.7	7.878	139.220	12.122	2.781	35.3
	20	5.609	4.159	2.092	0.468	8.3	7.837	132.292	11.801	2.639	33.7
OPEN	21	5.742	4.317	2.129	0.465	8.1	7.697	126.384	11.520	2.514	32.7
	22	5.630	4.385	2.143	0.457	8.1	7.347	123.210	11.361	2.422	33.0
	23	5.479	4.698	2.216	0.462	8.4	7.139	118.800	11.145	2.324	32.5
	24	5.717	5.810	2.462	0.503	8.8	6.919	114.960	10.953	2.236	32.3
	25	5.726	5.580	2.411	0.482	8.4	6.744	111.102	10.758	2.152	31.9
	26	5.715	5.368	2.363	0.463	8.1	6.536	107.914	10.594	2.078	31.8
	27	5.636	5.331	2.353	0.453	8.0	6.478	104.004	10.393	2.000	30.9
	28	5.593	5.191	2.320	0.438	7.8	6.291	101.235	10.246	1.936	30.8
	29	5.515	5.182	2.317	0.430	7.8	6.225	97.865	10.068	1.870	30.0
	30	5.590	5.175	2.314	0.422	7.6	6.068	95.315	9.930	1.813	29.9

crop-estimate for each of the dates. Yearly production was estimated as the difference between the April and September standing crops.

(iii) Stability, Diversity and Succession

In the descriptions of plant communities included in this report each is examined on the basis of stability, diversity and successional status. Estimates of diversity have been limited to examination of herb-layer components and have been limited to calculations of the average number of species per square meter in each of the vegetation types. Stability and succession have been evaluated on the basis of observational data with augmentation from structural data obtained as part of the additional sampling program.

3. Floristics

The Tract lies in the pinyon-juniper ecosystem of the Intermountain Region. The variation in vegetation encountered within this broad ecosystem type in the western United States is extreme. The Tract and its surrounding area, however, encompass only a slight portion of this variation. A second level of division categorizes 14 terrestrial vegetation types as set forth in Table V-30. The four major communities include: 1) pinyon-juniper woodland (Pinus edulis, Juniperus osteosperma), 2) chained pinyon-juniper rangeland (plateau shrublands), 3) upland sagebrush (Artemisia tridentata), 4) bottomland sagebrush (Artemisia tridentata); and the additional types include 5) Douglas-fir forest (Pseudotsuga menziesii), 6) mixed mountain shrubland (Quercus gambelii, Amelanchier alnifolia, Cercocarpus montanus, Symphoricarpos oreophilus), 7) bunchgrass (Oryzopis hymenoides, Agropyron spicatum), 8) marshlands (Typha latifolia, Phragmites communis), 9) riparian (Carex spp.), 10) Great-Basin wild rye (Elymus cinereus), 11) rabbitbrush (Chrysothamnus nauseosus) 12) greasewood (Sarcobatus vermiculatus), 13) agricultural meadows (Phleum pratense, Medicago sativa), and 14) annual weeds (Salsola kali, Lepidium montanum, Bromus tectorum).

The distribution of these types is mapped in Figure V-44. Chained pinyon-juniper rangelands are the most extensive vegetation type on the Tract. Approximately 45% of the Tract was chained during a range improvement program undertaken in 1966 by the Bureau of Land Management. The remaining pinyon-juniper woodlands are generally restricted to the sides and bottoms of the more shallow draws and to the ridgetops bounded by steeper valleys.

Sagebrush-dominated communities occur on plateau sites and in the valley bottoms. Plateau-sagebrush communities occur on ridgetops in large clearings in the original woodland. The bottomland communities occur on deep, alluvial deposits in the gulches. The sage in these communities grows much larger and more dense than on the ridgetops.

Douglas-fir forest occurs in isolated areas on the north-facing slopes of small, steep-sided gulches. The mixed-mountain-shrub communities are found infrequently on gentle, north-facing slopes. Rabbitbrush communities occur on alluvial deposits in gulch bottoms. The formation

Table V-30 COMMUNITY TYPES OF TRACT C-b

Vegetation Type	Dominant Species
Pinyon-Juniper Woodland	Pinyon pine Utah juniper Rocky Mountain juniper
Chained Pinyon-Juniper Rangeland	Big sagebrush Mountain mahogany Antelope bitterbrush
Upland Sagebrush	Big sagebrush
Bottomland Sagebrush	Big sagebrush Winterfat Rubber rabbitbrush
Douglas-fir Forest	Douglas-fir
Mixed Mountain Shrubland	Gambel's oak Serviceberry Mountain mahogany Snowberry Big sagebrush
Rabbitbrush	Rubber rabbitbrush
Greasewood	Greasewood
Bunchgrass	Indian ricegrass Blue-bunchwheatgrass Sulfur flower Sagewort Pasture sage
Marshlands	Cattail Common reed Sedge
Riparian	Sedges
Agricultural Meadows	Alfalfa Timothy Sedge
Annual Weeds	Russian thistle Pigweed Mountain peppergrass
Great Basin Wild Rye	Great Basin Wild Rye

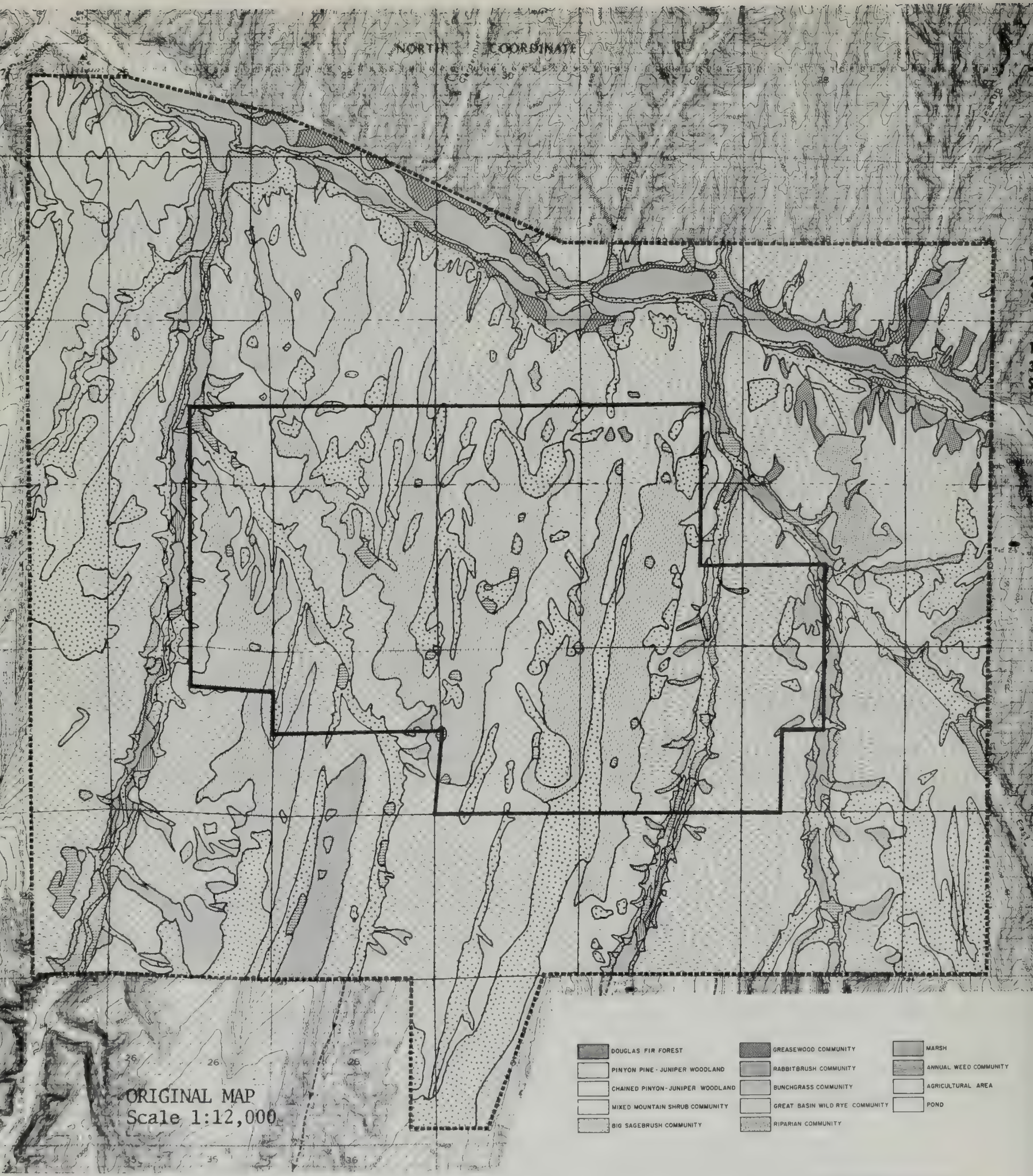


Figure V-44 VEGETATION MAP
TRACT C-b

of the rabbitbrush communities appears to be related to grazing practices in valley-bottom communities and appears to be successional to the bottomland-sagebrush stands. Greasewood stands occur locally on the toes of the alluvial fans, especially where high-salt concentrations are found. Bunchgrass stands occur on south-facing slopes in the major gulches on the colluvium deposited from the sides of the gulches. Marshlands are found along the major creek drainages, principally Piceance Creek, and are adjacent to the agricultural meadows located on the deep alluvium of these larger valleys. The annual-weed communities occur on randomly-located disturbed sites throughout the region.

The flora of the Tract and its surrounding area consist principally (approximately 78%) of species with characteristic North American distributions. Fifty-two percent of the species have temperate-American western distributions. The flora contain western species from two major floristic regions: the Rocky Mountain and the Intermountain West. Approximately 16% of the species in the area have been introduced primarily from European and Eurasian distributions. The flora of the area are listed in alphabetical order by common name, with the corresponding scientific name (Harrington, 1964; Weber,1972) in Table V-31. The annotated vascular flora including an alphabetical list of species by scientific name have been presented in Quarterly Data Report #3. It indicates appropriate abbreviations of life forms, a statement of relative abundance, community affinity, a statement indicating the geographical distribution of the species, whether the species is native or introduced, a statement indicating if the species is rare or endangered (if applicable), botanical family and synonomy (if applicable).

4. Terrestrial Plant Communities

The various types of plant communities existing on and around the Tract were defined by studying a total of 28 sampling stands. These stands are listed in Table V-32 and located in Figure V-45. The percent ground cover and the frequency of herbaceous plants in each of the stands are given in Tables V-33 and V-34, respectively. Stands 1 through 6 have been established as permanent plots for continuing studies. The productivity in these six stands is shown in Tables V-35 and V-36. Soil moisture contents in various locations on the Tract are shown in Table V-37. The soil moisture sampling locations are shown in Figure V-46. The plant communities defined from the stands study-data are described below.

(i) Pinyon-Juniper Woodlands

Pinyon-juniper woodlands are the most common and widespread vegetation type in this part of western Colorado. Total environmental characteristics favor the development of this type, but local soil, temperature, topographic and moisture conditions cause the mosaic of plant communities which occur in the region.

On Tract this vegetation type occurs primarily on ridges and dry slopes and is mostly absent from alluvial deposits, talus slopes and loamy soils of uplands. At one time these woodlands covered most of

Table V-31 ALPHABETICAL LISTING OF COMMON NAMES FOR THE FLORA OF TRACT C-b

Common Name	Scientific Name
TREES, SHRUBS, AND VINES	
Antelope bitterbrush	Purshia tridentata
Big sagebrush	Artemisia tridentata
Blue clematis	Clematis columbiana
Box elder	Acer negundo
Chokecherry	Prunus virginiana var. melanocarpa
Currant	Ribes cereum
Douglas-fir	Pseudotsuga menziesii
Four-winged saltbush	Atriplex canescens
Gambel's oak	Quercus gambelii
Golden currant	Ribes aureum
Greasewood	Sarcobatus vermiculatus
Horsebrush	Tetradymia canescens
Mormon tea	Ephedra viridis
Mountain mahogany	Cercocarpus montanus
Narrow-leaf cottonwood	Populus angustifolia
Oregon grape	Mahonia repens
Pinyon pine	Pinus edulis
Prickly pear	Opuntia polyacantha
Rabbitbrush	Chrysothamnus viscidiflorus
Rock spirea	Holodiscus dumosus
Rocky Mountain juniper	Juniperus scopulorum
Rubber rabbitbrush	Chrysothamnus nauseosus
Serviceberry	Amelanchier alnifolia
Shadscale	Atriplex confertifolia
Siberian elm	Ulmus pumila
Silver buffaloberry	Shepherdia argentea
Skunkbush	Rhus trilobata

Table V-31 ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Smooth currant	Ribes inerme
Snakeweed	Gutierrezia sarothrae
Snowberry	Symphoricarpos orephilus
Utah juniper	Juniperus osteosperma
Western virgin's-bower	Clematis ligusticifolia
Wild buckwheat	Eriogonum lonchophyllum
Wild hops	Humulus lupulus var. neomexicanus
Wild rose	Rosa woodsii
Willow	Salix sp.
Winter fat	Ceratoides lanata
HERBS	
Alfalfa	Medicago sativa
Alumroot	Heuchera parvifolia
Aster	Aster sp.
Balsam root	Balsamorhiza sagittata
Baltic rush	Juncus arcticus ssp. ater
Barnyard grass	Echinochloa crus-galli var. mitis
Bastard toadflax	Comandra pallida ssp. umbellata
Beard tongue	Penstemon sp.
Bee plant	Cleome serrulata
Biennial wormwood	Artemisia biennis
Blue-bunch wheatgrass	Agropyron spicatum
Blue grama	Bouteloua gracilis
Blue lettuce	Lactuca tatarica ssp. pulchella
Canada thistle	Cirsium arvense
Cattail	Typha latifolia
Cheatgrass	Bromus tectorum
Checker mallow	Sidalcea neomexicana
Cinquefoil	Potentilla gracilis
Clover	Trifolium gymnocarpon
Colorado bedstraw	Galium coloradoensis

Table V-31 ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Common reed	Phragmites australis
Common sunflower	Helianthus annuus
Crested wheatgrass	Agropyron desertorum
Curly-cup gumweed	Grindelia squarrosa
Dandelion	Taraxacum officinale
Darnel	Lolium perenne
Death camas	Zigadenus venenosus var. gramineus
Dock	Rumex sp.
Double bladderpod	Physaria floribunda
Easter daisy	Townsendia hookeri, Townsendia incana
Eriogonum	Eriogonum flexum
Evening primrose	Calylophus hartwegii ssp. lavandulifolius Oenothera trichocalyx, Oenothera sp.
Evening star	Mentzelia rusbyi, Mentzelia sp.
Fairy candelabra	Androsace septentrionalis
False dandelion	Agoseris glauca
False flax	Camelina microcarpa
False gromwell	Onosmodium molle var. occidentalis
False Solomon's seal	Smilacina stellata
Fireweed	Epilobium sp.
Foxtail barley	Hordeum jubatum
Glaucous aster	Aster glaucodes
Goat's beard	Tragopogon dubius
Golden aster	Heterotheca villosa
Golden ragwort	Senecio multilobatus
Goldenrod	Solidago sparsiflora
Golden smoke	Corydalis aurea
Goldenweed	Haplopappus nuttallii
Goosefoot	Chenopodium fremontii, Chenopodium sp.
Great Basin wildrye	Elymus cinereus
Green sage	Artemisia dracunculus ssp. glauca
Gumbo lily	Oenothera caespitosa
Horsetail	Equisetum arvense

Table V-31 ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Horseweed	Conyza canadensis
Indian paintbrush	Castilleja chromosa, Castilleja linariaefolia
Indian ricegrass	Oryzopsis hymenoides
Japanese brome	Bromus japonicus
Junegrass	Koeleria gracilis
Kentrophyta milk vetch	Astragalus kentrophyta
Kentucky bluegrass	Poa pratensis
Larkspur	Delphinium nelsoni
Little ricegrass	Oryzopsis micrantha
Long-leaved phlox	Phlox longifolia
Lupine	Lupinus argenteus, Lupinus sp.
Malcolmia	Malcolmia africana
Mariposa lily	Calochortus gunnisoni, Calochortus nuttallii
Marsh elder	Iva xanthifolia
Meadow goldenrod	Solidago canadensis
Miner's candle	Cryptantha sp.
Moss phlox	Phlox hoodii
Mountain peppergrass	Lepidium montanum
Much-branched gayophytum	Gayophytum ramosissimum
Mutton grass	Poa fendleriana
Needle-and-thread grass	Stipa comata
Nodding brome	Bromus porteri
Nodding eriogonum	Eriogonum cernuum
Nuttail's sunflower	Helianthus nuttallii
Orchard grass	Dactylis glomerata
Pasque flower	Pulsatilla patens ssp. multifida
Pasture sage	Artemisia frigida
Peppergrass	Lepidium perfoliatum
Phacelia	Phacelia idahoensis
Pigweed	Amaranthus retroflexus
Prairie bulrush	Scirpus paludosus
Prickly lettuce	Lactuca serriola

Table V-31 ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Puccoon	*Lithospermum* sp.
Pussytoes	*Antennaria rosea*, *Antennaria parvifolia*
Rabbit's-foot grass	*Polypogon mouspelliensis*
Ragweed	*Ambrosia artemisiifolia*
Ragwort	*Senecio eremophilus* var. *kingii*
Red top	*Agrostis gigantea*
Rock cress	*Arabis holboellii*
Russian thistle	*Salsola iberica*
Sagewort	*Artemisia ludoviciana*
Sand dropseed	*Sporobolus cryptandrus*
Scarlet gilia	*Ipomopsis aggretata*
Scarlet globe mallow	*Sphaeralcea coccinea*
Scouring rush	*Equisetum hyemale*, *Equisetum laevigatum*
Seaside arrowgrass	*Triglochin maritima*
Sheep fescue	*Festuca brachyphylla*
Shore buttercup	*Ranunculus cymbalaria*
Short-rayed alkali aster	*Brachyactis frondosa*
Showy milkweed	*Asclepias speciosa*
Skeletonweed	*Lygodesmia grandiflora*
Slender wheatgrass	*Agropyron trachycaulum*
Sloughgrass	*Beckmannia syzigachne*
Smooth brome	*Bromus inermis*
Sow thistle	*Sonchus arvensis*
Speedwell	*Veronica salina*
Spreading dogbane	*Apocynum androsaemifolium*
Spurge	*Chamaesyce* sp., *Euphorbia robusta*
Squirreltail grass	*Sitanion longifolium*
Stickseed	*Lappula redowskii*
Stinging nettle	*Urtica dioica*
Sugarbowls	*Clematis hirsutissima*
Sulphur flower	*Eriogonum umbellatum*
Sweet vetch	*Hedysarum boreale*
Tansy mustard	*Descurainia pinnata*

Table V-31 ALPHABETICAL LISTING OF COMMON NAMES OF THE FLORA OF TRACT C-b (Continued)

Common Name	Scientific Name
Tassel-flower brickellbrush	Brickellia grandiflora
Thistle	Cirsium sp.
Timothy	Phleum pratense
Tule	Scirpus lacustris ssp. validus
Tumble mustard	Sisymbrium altissimum
Twistflower	Streptanthus cordatus
Umbrellawort	Oxybaphus linearis
Utah daisy fleabane	Erigeron utahensis
Watercress	Rorippa nasturtium-aquaticum
Western wheatgrass	Agropyron smithii
White pigweed	Amaranthus albus
White sweet clover	Melilotus alba
Wild flax	Linum lewisii
Wild licorice	Glycyrrhiza lepidota
Winged eriogonum	Eriogonum alatum
Wing-fruited sand verbena	Tripterocalyx micranthus
Yarrow	Achillea lanulosa
Yellow evening primrose	Oenothera strigosa
Yellow sweet clover	Melilotus officinalis
Yucca	Yucca glauca

Table V-32 VEGETATION SAMPLING STANDS

STAND NUMBER	STAND TYPE
1f & 1–0	Chained Pinyon-Juniper Rangeland (Experimental Site)
2f & 2–0	Chained Pinyon-Juniper Rangeland (Control Site)
3f & 3–0	Upland Sagebrush Community
4f & 4–0	Bottomland Sagebrush Community
5f & 5–0	Pinyon-Juniper Woodland (Experimental Site)
6f & 6–0	Pinyon-Juniper Woodland (Control Site)
7	Chained Pinyon-Juniper Rangeland
8	Upland Sagebrush Community
9	Pinyon-Juniper Woodland (East-facing Slope)
10	Chained Pinyon-Juniper Rangeland
11	Upland Sagebrush Community
12	Pinyon-Juniper Woodland
13	Pinyon-Juniper Woodland
14	Chained Pinyon-Juniper Rangeland
15	Upland Sagebrush Community
16	Bottomland Sagebrush Community
17	Rabbitbrush Community
18	Greasewood Community
19	Bottomland Sagebrush Community
20	Bunchgrass Community
21	Douglas-fir Forest
22	Annual Weed Community
23	Annual Weed Community
24	Annual Weed Community
25	Annual Weed Community
26	Annual Weed Community
27	Annual Weed Community
28	Annual Weed Community

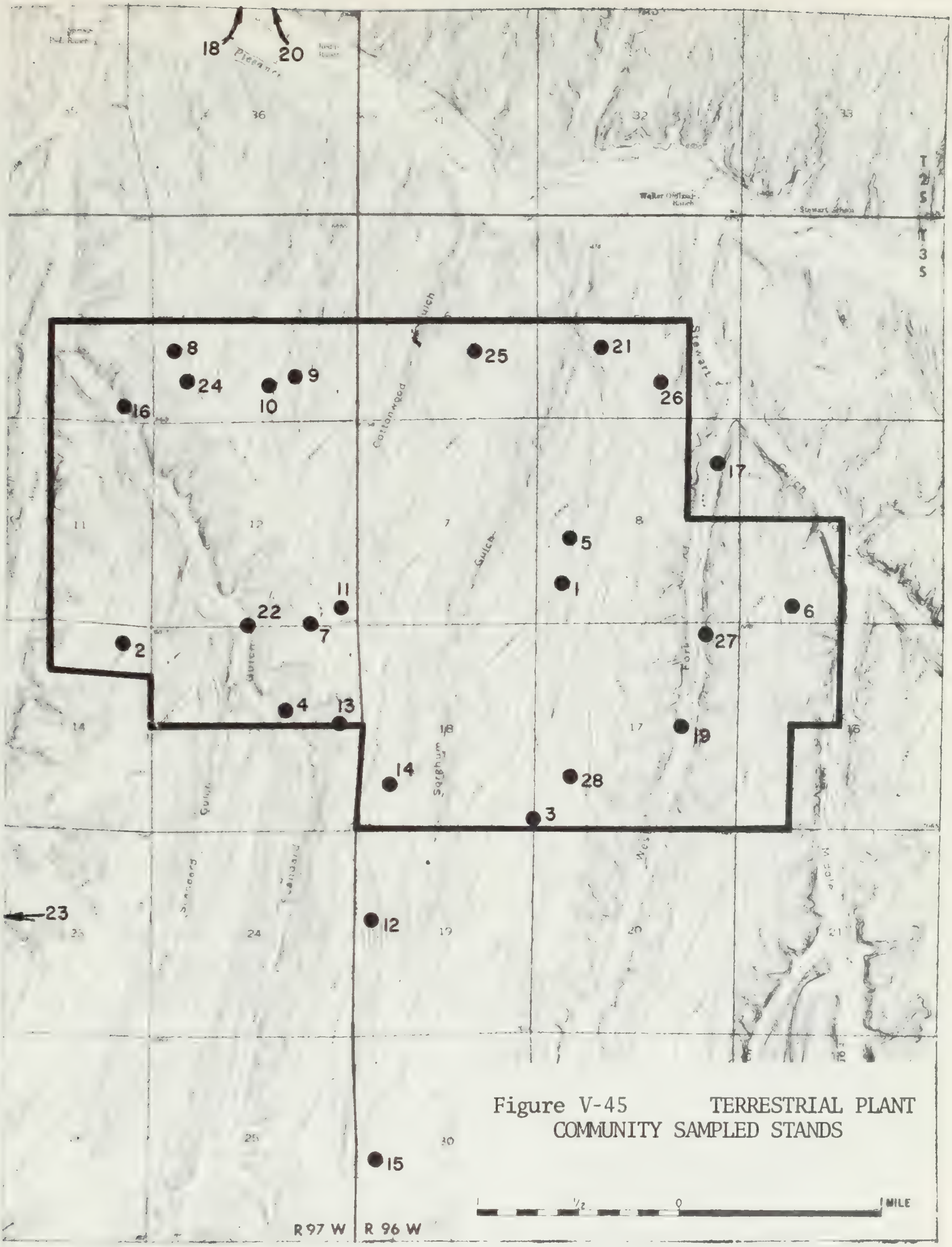


Figure V-45 TERRESTRIAL PLANT COMMUNITY SAMPLED STANDS

Table V–33 PERCENT GROUND COVER IN HERBACEOUS PLANT SAMPLING STANDS

STAND NO.

COVER CATEGORIES	1-0	1-f	2 0	2 f	3-0	3 f	4-0	4-f	5-0	5-f	6-0	6-f	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Herbaceous Plants (% Cover)	15	23	26	44	30	44	17	14	7	9	11	22	42	46	22	38	63	20	26	36	43	27	51	43	17	29	13	46	82	38	30	50	34	4
Woody Plants 25 cm (% Cover)	1	–	–	–	1	1	2	2	–	–	–	–	1	2	< 1	–	1	< 1	–	2	4	3	2	2	4	–	1	2	–	–	–	–	–	
Mosses (% Cover)	1	–	1	–	6	1	27	35	3	4	8	2	1	1	< 1	–	1	< 1	3	< 1	2	1	5	–	–	–	10	–	–	–	–	–	–	–
Crustose Lichens (% Cover)	1	–	–	1	–	–	–	–	2	–	–	–	–	–	< 1	–	–	< 1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	
Foliose & Fruticose Lichens (% Cover)	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	5	1	–	2	–	< 1	–	–	–	–	–	4	–	–	–	–	–	–	–
Litter Cover (% Cover)	63	70	58	64	26	40	82	59	83	82	74	71	71	69	48	57	81	81	72	72	66	77	80	76	77	35	43	38	62	36	8	20	38	2
Bare Soil (% Cover)	31	26	24	23	51	19	7	17	15	14	23	29	26	31	33	41	19	18	22	28	32	20	13	21	18	42	3	26	14	38	70	36	56	94
Rock (% Cover)	3	2	2	3	–	–	–	–	2	2	–	–	1	2	18	3	1	< 1	2	< 1	< 1	–	1	–	1	13	5	–	–	4	–	4	6	6

Table V-34 PERCENT FREQUENCY OF HERBACEOUS PLANTS IN SAMPLED STANDS

STAND NO.

SPECIES	1-0	1-f	2-0	2-f	3-0	3-f	4-0	4-f	5-0	5-f	6-0	6-f	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Agoseris glauca	8	8		8	100	88				4	40	48		5		5	10				20													
Agropyron cristatum																								100										
Agropyron dasystachum																				25							30							
Agropyron desertorum	44	36	36	36					12	24			5	20	10	40	5						15	10										
Agropyron smithii	24	16	20	32	100	100	56	44		16	76	72	85	80	80	55	100	80	60	55	100	70	95	55	10	10		90	10	30	10	30	100	
Agropyron spicatum		4		4					8	4																								
Agropyron trachycaulum	4						4									10						10	5			10								
Allium acuminatum																					15													
Amaranthus albidus																												100	90				20	
Amaranthus graecizans																																		10
Androsace septentrionalis									4							10			35			5					60							
Antennaria parvifolia		8			20	28						8	15	25	5	15			10	20														
Antennaria rosea	20	12	4	12		4					48	40			5			5	25	20							50							
Arabis holboellii	16	8	32	12	84	80			12	28	24	36			5		10	20	15	15	20						50							
Artemisia dracunculus																							20			10							10	
Artemisia frigida								4																		40								
Artemisia ludoviciana	12	8										4	5						5			65	10		30									
Aster adscendens																			5															
Aster fendleri *																				40														
Astragalus ceramicus *			8	4								4		45	25		25		10							5								
Astragalus kentrophyta	8	28								4	32	36	5	25	10		5		5							10								
Astragalus pectinatus *						20							5	5		25					10													
Astragalus purshii					32	16					4		15					10			15										20			
Astragalus scopulorum						12															30													
Astragalus spatulatus					24	12										20				30														
Balsamorhiza sagittata																		20		5	15													
Bouteloua gracilis	4		12	12			12					4				10						20												
Brickellia grandiflora *																										60								
Bromus anomalus																											10							
Bromus inermis																							30											
Bromus japonicus																																70	30	40
Bromus marginatus *																			15															
Bromus tectorum	92	76	100	96		4	100	100	24	36	16		20	10	10			25	10	55		100	95	75	100	35		100	100	80	100	100	60	80
Calochortus nuttallii	8				100	100					8	16	5				15	15			35													
Calylophus hartwegii var lavandulaefolius												64																						
Carex sp	16							4								45		35																
Carex pensylvanica *	16	32	4		96	80			32	28	12	56	40	35	40		50	55		15	45						40			10				
Castilleja chromosa					12	64								5			65				55													
Castilleja linaraeifolia					24																													
Chaenactis douglasii	12	8								4						15					5										10	10		
Chamaesyce glyptosperma*																												10						
Chenopodium album	28	20	64	24			68	40	24	32	24	20	40		15		25	10		20	25					15	20	70			60		40	20
Chenopodium sp															20							55	55	20	25					50				
Cirsium arvense																														10				
Cirsium sp								4	4						10				5							15								
Cleome serrulata																							5											
Collinsia parviflora		12	8						40	60	12	8	15				5	10			85						20							
Collomia linearis																					40													
Comandra umbellata var pallida											12	60		5	35	20	5	10	10		30											10		
Crepis acuminatus													5	15	10		35	60	5	30	80													
Cruciferae (unknown)															5																			
Cryptantha sp	8	24							24	16			5			10			10	20													10	10
Cymopterus montanus *	12										28	12																						
Delphinium nelsoni			4			4							5																					
Descurainia pinnata	40	24	24	16			40	28	44	32	4	12	15	5	10	5			10			15	15	10				10		10	10			
Draba reptans				4					8	4																								
Elymus cinereus																								25										

*Tentative Species Identification

Table V-34 (Continued)

	STAND NO.																																	
	1-0	1-f	2-0	2-f	3-0	3-f	4-0	4-f	5-0	5-f	6-0	6-f	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Erigeron aphanactus *	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Erigeron filifolius*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Erigeron pumila *	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Erigeron sp.	–	20	20	16	76	96	–	–	4	–	40	56	50	–	–	–	–	70	5	35	100	–	–	–	–	25	50	–	–	20	–	–	–	–
Erigeron utahensis	–	–	–	–	–	–	–	–	–	–	–	–	5	70	20	10	55	–	5	–	–	–	–	10	–	–	–	–	–	–	–	–	–	–
Eriogonum alatum	–	–	–	–	–	16	–	–	–	–	–	–	–	–	40	40	5	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eriogonum heracleoides *	–	–	–	–	–	–	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eriogonum lonchophyllum	–	–	–	–	–	–	–	–	–	–	–	–	5	–	20	30	–	–	10	–	–	–	–	–	–	55	–	–	–	–	–	–	–	–
Eriogonum strictum *	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Eriogonum umbellatum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15	5	–	–	5	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–
Erodium cicutarium	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Erysimum asperum	–	–	–	–	–	–	–	–	12	12	4	–	–	–	–	5	–	5	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–
Euphorbia robusta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Festuca brachyphylla	4	12	–	4	64	84	–	–	4	4	36	68	45	15	–	–	25	85	–	45	75	–	–	–	–	–	60	–	–	–	–	–	–	–
Gayophytum ramocissimum	12	12	44	36	–	24	–	–	–	–	4	–	5	–	–	–	–	5	–	–	5	–	–	–	–	–	–	–	–	10	–	10	–	–
Haplopappus nuttallii	–	16	–	–	–	–	–	–	–	–	8	–	–	20	90	85	–	–	5	30	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hedysarum boreale	–	–	–	–	16	16	–	–	–	–	–	–	5	–	–	5	25	–	–	5	10	–	–	–	–	–	–	–	–	–	–	–	–	–
Heterotheca villosa	–	–	12	8	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Heuchera parvifolia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	20	–	–	–	–	–	–	–
Hymenopappus filifolius *	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hymenopappus lugens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hymenoxis acaulis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ipomopsis aggregata	4	–	–	–	–	–	–	–	–	–	–	–	–	5	–	30	–	10	10	5	–	–	–	–	5	–	–	–	–	–	–	–	–	–
Kochia scoparia *	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–				–	–	–	10	25			–	–	–	–	–	–	–	–
Koeleria gracilis (cristata)	4	32	8	12	100	100	–	–	–	–	24	64	55	90	30	40	100	65	45	50	100					–	30	–	–	–	–	–	–	–
Lactuca serriola	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–
Lappula redowskii	8	12	36	24	–	–	52	16	–	–	8	8	30	–	–	–	–	–	5	–	–	40	50	–	–	–	–	10	–	–	10	10	–	–
Lepidium densiflorum	–	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–
Lepidium montanum	–	–	–	–	–	–	28	48	–	–	–	–	–	–	40	–	–	–	–	–	–	40	100	5	50	–	–	60	–	–	–	–	20	–
Linum lewisii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lithospermum sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lolium perenne	–			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	20	–	10
Lomatium grayi *	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	30	–	–	–	–	–	–	–	–	–	–	–	–	–
Lomatium orientale *	–	–	–	–	72	80	–	–	–	–	4	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lupinus argenteus	4	–	–	–	–	12	–	–	–	–	–	–	10	–	–	–	–	10	15	–	25	–	–	–	–	–	–	–	–	–	–	–	–	–
Marrubium vulgare	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–
Mentzelia dispersa	8	8	–	8	–	–	–	–	–	–	–	–	10	–	–	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	40	20	–	–
Microperis cuspidata *	–	–	–	–	–	–	–	–	–	–	–	–	–	15	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Microseris sp. *	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Microsteris micrantha	–	8	8	4	100	100	–	–	–	–	–	–	5	–	–	–	–	45	–	–	90	–	–	–	–	–	–	–	–	–	–	–	–	–
Nicotiana attenuata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oenothera caespitosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	20	–	–	5	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–
Orobanche fasciculata	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oruzopsis hymenoides	48	64	12	16	–	–	20	32	68	48	4	12	50	30	45	40	75	–	35	55	–	5	–	–	45	90	–	30	–	40	80	80	30	10
Oryzopsis micrantha	–	–	–	–	–	–	20	–	24	32	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	30	–	–	–	–	–	–	–
Oxytropis sp	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Penstemon fremontii	–	–	–	–	52	52	–	–	–	4		–	–	5	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Penstemon lentus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–
Penstemon sp.	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	15	–	–	–	–	–	–	–	–
Penstemon watsoni	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Phlox hoodii	–	32	–	100	88	–	–	–	–	–	40	64	70	85	35	60	70	45	25	25	–	–	–		–	–	–	–	–	–	–	–	–	–
Phlox longifolia	8	–	4	12	96	100	–	4		4	64	68	–	30	5	15	10	55	5	–	100	–	–	–		–	–	–	–		–	–	–	–
Physaria floribunda	–	8	–	–	–	–	8	12	4	–	–	–	–	–	30	85	–	–	15	5	35	–	–	–	–	–	–	–	–	–	–	–	–	–
Poa fendleriana	–	–	–	–	64	92	–	–	20	20		40	–	–	–	25	–	–	50	–	–	–	–	–	–		10	–	–	–	–	10	–	–
Poa pratensis	–	4	8	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–	–	–	–	10		–		–	–
Poa sp	–	36	28	24		–	16	4	–	–	–	–	10	45	15	–	–		–	–	–	25	75	–	–	–						–	–	
Polemoniaceae (unknown)	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	60				–		–	–

*Tentative Species Identification

Table V-34 (Continued)

STAND NO.

	1-0	1-f	2-0	2-f	3-0	3-f	4-0	4-f	5-0	5-f	6-0	6-f	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Polygonum douglasii	–	–	–		–	–	–	–	–	–	–	–		–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–				–
Polygonum rurivagum	–		4	4	–	–	–	–	–	–	4	8	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–			50		–	–
Polygonum sawatchense	12	4		–	–	24	–		–	–	–	–		–	–	–	–	50	–	–	95	–	–	–	–	–	–	–	–	–	–	–	–	–
Polygonum sp			–	–			–		–	–	–	–	–	10	–	–	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Salsola kali	–			–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	5	–	–	30	–	100	40	50	10	20	80	30
Senecio ambrosioides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Senecio fremontii *	–	–	–	–			–	–	–	–	–	–	–	–	–	15	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–		–
Senecio multilobatus		12	–	–		–		4		4	12	–	15	15	–	5	15	–	30	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Senecio sp	–	–	–	–	–	–	–	–	–	–		–	–	–	10	–	–	–	5	–	–	–	–	–	–	–	40	–		–	–	–	–	–
Sisymbrium altissimum	–	–	–	–	–	–	–	–	–	–	–	–	–		5	–		–	–	–	–	–	–	–	–	–	–	80	90	90	–	20	–	10
Sisymbrium sp.	–	–		4	–	–	–		–	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sitanion longifolium	20	44	36	36	–	–			72	72	8	4	25	–	5	–		15	10	35	–	5	–	–	–	–	30	–	–	10	–	–	–	–
Sphaeralcea coccinea		–	8	4	68	36	–		–	–	20	20	–	15	–	5	95	20	5	20	40	25	5	–	5	–	–	–	–	–	–	–	–	–
Sporobolus cryptandrus *				–	–					–	–	–		–	–	–	–	–	–	–		40	–	–	35	–	–	–	–	–	–	–	–	–
Stephanomeria tenuifolia	–	–	–	–	–	–	–	–	–	–	8	20	–	–	–	40	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Stipa comata	20	16	–	4	8	36	8	8	–	4	40	28	50	25	20	50	30	70	50	–	65	80	–	–	–	–	–	–	–	–	–	–	–	–
Streptanthus cordatus	–	–	–	–	–	–	–	–	–	8	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Taraxacum officinale	4	8	16	8		4		4		–				–	–	–	–	15	–	15	–	–	–	–	–	–	20	–	–	10	–	–	10	–
Townsendia sericea	4		–	–	8	–	–	–	–	–	–	–	5	35	–	15	–	–	–	10	–	–	–	–	–	–	–	–	–	–		–	–	
Tragopogon dubius	4	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–
Trifolium gymnocarpon	–	–	–	–	96	88	–	–	–	–	–		5	–	–	–	–	–	–	–	95	–	–	–	–	–	–	–	–	–	–	–	–	–
Viola nuttallii	–		–				4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Yucca glauca	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Zigadenus venenosus		4				16	–	–	–	–	–	8	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Unknown mustard	–	–	4	4	–	–	24	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	–	–	–	–	–	–
Unknown #1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	5	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–
Unknown #3				–			–	–	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Unknown #4			–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Unknown #5					–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		–							–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
(Woody species) < 25cm	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amelanchier alnifolia	–	4	4	–	–	–	–	–	–	–	4	–	–	–	–	–	5	–	–	10	5	–	–	–	–	–	–	–	–	–	–	–	–	–
Artemisia tridentata	12	12	4	8	44	88	44	64	–	–	8	–	20	50	–	15	–	10	–	–	85	20	–	–	20	–	–	–	–			–		–
Artriplex canescens							–	–		–	–		–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Atriplex confertifolia					–		–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	60	–	–	–	–	–	–	–	–
Ceratoides lanata			–		8	16	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	20	–
Cercocarpus montanus					–			–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chrysothamnus nauseosus		4	16	8			–	–	–	–	4	–	–	–	–	–	–	–	–		–	5	20	5	5	–	–	10	–	–	–	–		–
Chrysothamnus viscidiflorus			4				–	–	–	–	–		10	–	–	–	–	5	20	–	60	–	–	–	–	–	–	–	–	–	–	–	–	
Gutierrezia sarothrae	12	24	–		12	24	–	–	–		–		15	65	15	50	40	–	5	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Juniperus osteosperma						–		–	–	4	–			–	–	–	–	–	–	–	–	–	–	–	–	–		–	–		–	–	–	–
Juniperus scopulorum				–	–	–	–	–	–	–			–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mahonia repens						–	–	–		–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Opuntia polyacantha			–	–	–	–	–	–		–	–	–	5	5	–	–	–	5	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–
Pseudotsuga menziesii				–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	10	–	–	–	–	–	–	–
Purshia tridentata	4	–	–	4		–	–	–	4	–	–		5	–	–	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Quercus gambelii			–	–	–		–			–	–	–	–	–	–	5	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sarcobatus vermiculatus	–	–					–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15	–	–	–	–	–	–	–	–	–	–
Symphoricarpos oreophilus	8	–	–	4	–	–	4		–	–	–	–	25	–	–	–	–	5	15	5	5	–	–	–	–	–	80	–	–	–	–	–	–	–
Tetradymia canescens			–	–	–	–		–	–	–	–			–	–	–	70	10	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pinus edulis	4	–	–	4	–	–	–	–	8	4	12			5	–	–	–	15	5	5	–	–	–	–	–	–	20	–	–	–	–	–	–	–
Aster sp	4	16		12	–	–	–	–		4	–	–	5	5	–	10		–	–	–	–	–	15	20	–	–	–	–	–	–	–	–	–	–
Melilotus officinalis	–			–	–	–			–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50	–

* Tentative Species Identification

Table V-35 MEAN HERB PRODUCTIVITY FOR PERMANENT PLOTS 1 THROUGH 6*

	May	June	July	August
Stand 1, Chained Pinyon-Juniper Rangeland (Experimental Site)				
lbs/A	124 ± 22	314 ± 43	542 ± 162	255 ± 72
(Kg/HA)	(139 ± 25)	(352 ± 48)	(607 ± 181)	(286 ± 81)
Stand 2, Chained Pinyon-Juniper Rangeland (Control Site)				
lbs/A	127 ± 26	282 ± 40	376 ± 120	228 ± 52
(Kg/HA)	(142 ± 29)	(316 ± 45)	(421 ± 135)	(255 ± 58)
Stand 3, Upland Sagebrush Community				
lbs/A	268 ± 18	464 ± 45	499 ± 37	346 ± 39
(Kg/HA)	(300 ± 20)	(520 ± 50)	(559 ± 42)	(388 ± 44)
Stand 4, Bottomland Sagebrush Community				
lbs/A	72 ± 14	278 ± 33	227 ± 61	120 ± 24
(Kg/HA)	(79 ± 16)	(312 ± 37)	(254 ± 68)	(135 ± 27)
Stand 5, Pinyon-Juniper Woodland (Experimental Site)				
lbs/A	64 ± 16	171 ± 37	207 ± 80	128 ± 46
(Kg/HA)	(72 ± 18)	(192 ± 42)	(232 ± 90)	(143 ± 51)
Stand 6, Pinyon-Juniper Woodland (Control Site)				
lbs/A	107 ± 19	220 ± 41	209 ± 35	270 ± 50
(Kg/HA)	(120 ± 21)	(246 ± 46)	(234 ± 39)	(303 ± 56)

* Plus and minus values are equal to standard error of the mean.

Table V-36 SHRUB STANDING CROP ESTIMATES FOR APRIL AND SEPTEMBER 1975, TRACT C-b

	Stand No.	Clipping Date	Amsp	Artr	Chna	Cemo	Juos	Pied	Putr	Cela	Total	lbs/A/ yr	Kg/ HA/yr
Chained pinyon - juniper range - land	1	April 1975	18 ± 4*	1185 ± 412	142 ± 27	86 ± 22	24 ± 3	44 ± 6	75 ± 13	-	1574 ± 487		
		Sept. 1975	88 ± 41	1955 ± 449	172 ± 48	216 ± 70	41 ± 8	70 ± 15	201 ± 39	-	2743 ± 670		
		Total Production									1169		
	2	April 1975	82 ± 24	137 ± 34	180 ± 34	46 ± 13	93 ± 12	59 ± 8	62 ± 14	-	659 ± 139		
		Sept. 1975	63 ± 22	263 ± 98	218 ± 62	114 ± 42	157 ± 28	94 ± 20	289 ± 48	-	1198 ± 320		
		Total Production									539	854	968
Upland sagebrush	3	April 1975	44 ± 13	1352 ± 256	8 ± 2	-	2 ± 0.5	16 ± 2	-	-	1422 ± 274		
		Sept. 1975	56 ± 22	2307 ± 599	10 ± 2	-	3 ± .5	25 ± 5	-	-	2401 ± 628		
		Total Production									979	979	1097
Bottomland sagebrush	4	April 1975	-	6094 ± 1868	35 ± 6	-	-	-	2 ± 0.5	30 ± 4	6161 ± 1878		
		Sept. 1975	-	13838 ± 4534	42 ± 12	-	-	-	7 ± 1	20 ± 3	13927 ± 4550		
		Total Production									7776	7766	8701
Pinyon-juniper woodland	5	April 1975	93 ± 27	34 ± 6	4 ± 1	48 ± 13	10 ± 2	14 ± 1	18 ± 4	-	221 ± 55		
		Sept. 1975	117 ± 46	58 ± 15	5 ± 1	118 ± 42	16 ± 2	22 ± 5	87 ± 14	-	423 ± 125		
		Total Production									202		
	6	April 1975	78 ± 22	245 ± 46	66 ± 12	-	26 ± 4	20 ± 2	1.5 ± 0.5	-	436 ± 86		
		Sept. 1975	98 ± 38	418 ± 107	79 ± 22	-	44 ± 8	30 ± 7	7 ± 1	-	676 ± 183		
		Total Production									240	221	248

Amsp - Amelanchier alnifolia
Artr - Artemisia tridentata
Chna - Chrysothamnus nauseosus
Cemo - Cercocarpus montanus

Juno - Juniperus osteosperma
Pied - Pinus edulis
Putr - Purshia tridentata
Cela - Ceratoides lanata

* values are in lbs/A

Table V-37 SOIL MOISTURE CONTENTS
IN TRACT C-b VEGETATION TYPES
SOIL MOISTURE

	MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPT.		OCT.	
SAMPLE NO. LOCATION	%	depth	%	depth	%	depth	%	depth	%	depth	%	depth	%	depth	%	depth
1. Chained Pinyon-Juniper Rangeland	80.0	10"	100	10"	38	10"	69.5	10"	43.5	10"	34.5	10"	30.5	10"	30.5	10"
2. Chained Pinyon-Juniper Rangeland	27.8	8"	78	10"	39	10"	55.0	10"	34.0	10"	28.0	10"	24.5	10"	25.0	10"
3. Upland Sagebrush	47.0	8"	85	18"	41	10"	69.0	10"	36.0	10"	36.0	10"	29.5	10"	39.5	10"
4. Bottomland Sagebrush	32.0	16"	76	8"	32	18"	60.0	18"	41.0	18"	28.0	18"	23.0	10"	27.0	10"
5. Pinyon-Juniper Woodland	37.0	10"	82	10"	29	10"	49.0	10"	28.0	10"	25.5	10"	20.5	10"	21.5	10"
6. Pinyon-Juniper Woodland	–	–	83	20"	40	20"	68.5	20"	50.0	10"	42.0	10"	39.0	10"	34.0	10"
7. Chained Pinyon-Juniper Rangeland	–	–	70	10"	–	–	65.0	20"	36.5	10"	40.0	10"	28.0	10"	29.0	10"
8. Bunchgrass Community	31.0	8"	39	17"	14	18"	–	–	–	–	18.0	10"	20.0	10"	13.0	10"
9. Bottomland Sagebrush	23.0	17"	55	15"	21.5	15"	35.0	20"	20.5	10"	21.0	20"	12.0	10"	18.0	10"
10. Rabbitbrush Community	–	–	–	–	–	–	33.9	15"	21.0	10"	22.0	10"	22.0	10"	21.0	10"
11. Bunchgrass Community	33.5	7"	45	7"	20.5	7"	39.0	10"	24.0	10"	23.0	10"	14.0	7"	14.0	7"
12. Bottomland Sagebrush	25.0	18"	40	15"	25.0	20"	45.0	15"	28.0	10"	24.0	10"	22.0	10"	22.0	10"
13. Mixed Mountain Shrubland	44.5	8"	25	8"	28.5	10"	53.0	10"	45.0	10"	37.0	10"	32.0	10"	31.0	10"
14. Pinyon-Juniper Woodland	31.5	18"	77	18"	35.5	20"	58.0	20"	35.0	10"	32.0	10"	30.0	10"	26.0	10"
15. Cottonwood Community	45.5	10"	–	–	40.5	10"	67.0	10"	33.0	10"	19.0	10"	25.0	10"	26.0	10"
16. Bottomland Sagebrush	–	–	–	–	33.5	20"	58.0	10"	35.0	10"	33.0	10"	30.0	10"	29.0	10"
17. Annual Weed Community	62.5	12"	50	8"	34.5	20"	60.5	20"	46.0	10"	24.5	10"	–	–	–	–

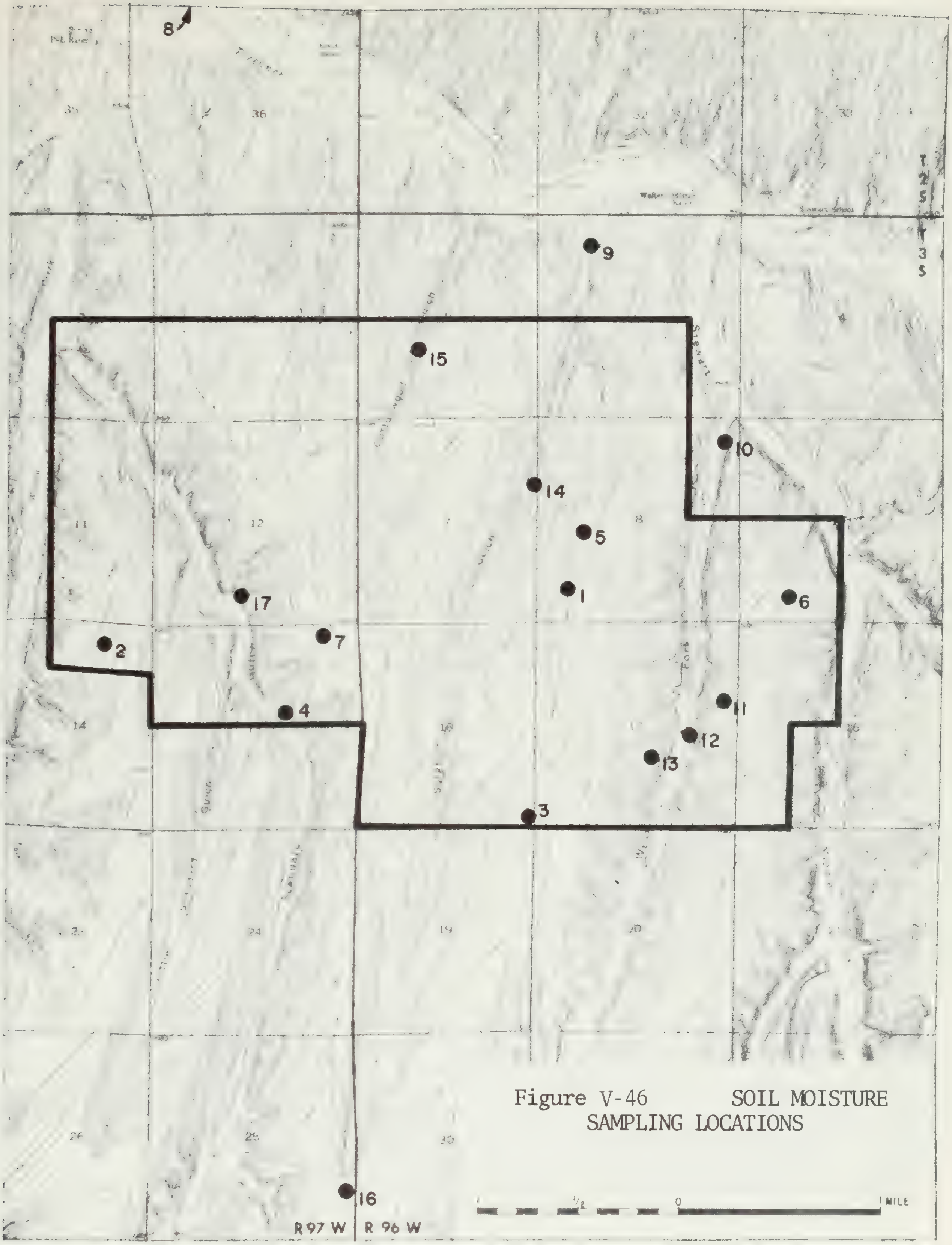


Figure V-46 SOIL MOISTURE SAMPLING LOCATIONS

the Tract, however Bureau of Land Management (BLM) chaining operations in 1966 removed approximately 2500 wooded acres within the Tract boundaries. Even though the total extent of the pinyon-juniper woodlands was reduced by more than 50%, it remains as one of the most common vegetation types on the Tract.

Structure and Composition

The tree layer of these woodlands is composed of varying amounts of pinyon pine, Utah juniper and Rocky Mountain juniper. Composition percentages vary from nearly pure stands of pinyon pine on broad ridges to steeply-sloping sites where Utah juniper is the dominant species. All stands of this vegetation type, regardless of dominant species, tend to have limited canopy cover (32%) and low density (approximately 210 trees per hectare, Table V-38). The open canopy and wide spacing of individuals alter incoming solar radiation and seem to have a limited effect on understory development. Competition for water and nutrients tends to restrict the growth of shrubby and herbaceous plants.

Most of woodlands on the Tract have poorly developed herb and shrub layers. Shrub-layer dominants vary from site to site. Big sagebrush usually occurs as the dominant species on ridgetop stands. Species more characteristic of mixed mountain shrublands (serviceberry, bitterbrush and mountain mahogany) tend to dominate stands located on hillsides. In the open understory stands, shrub cover averages 4%, and total shrub density averages approximately 3200 shrubs per hectare (Tables V-39, -40, -41 and -42). Herb cover in these same stands averages 15% with western wheatgrass, fleabane, sheep fescue, Junegrass, neddle-and-thread grass, and Indian ricegrass occurring as dominant species (Tables V-33 and -34, Stands 5-0, 5-f, 6-0, 6-f, 9 and 12).

Pinyon-juniper woodlands also occur to a limited extent on north-facing slopes. In these stands the understory is much more dense and has the appearance of a mixed shrub community except for the presence of the trees. Shrub cover and density are much greater (24% and 26,000 individuals per hectare, respectively). The dominant shrub species in these stands is snowberry (Table V-43). The herb layer is much better developed in these stands and herb cover averages 26%. Common understory species are fairy, candelabra, Junegrass, western wheatgrass and needle-and-thread grass (Tables V-32 and V-34, Stand 13). Pasque flower and sugar bowls, rare species on the Tract, occur in these pinyon-juniper stands.

Considerable variability exists among pinyon-juniper woodlands. Average shrub layer similarity among all sampled pinyon-juniper stands is 48% (Table V-44). Similarity is calculated on the basis of the formula $C = [2w/(a + b)] \times 100$, where C = similarity index, w = sum of importance value shared by each species in compared stands, a = sum of importance value in Stand A, and b = sum of importance value in Stand B. Average similarity is computed by determining the arithmetic mean of similarity indices between all possible stand combinations.

TABLE V-38.

TREE DATA SUMMARIES
C-b 1975

	% Frequency	Density Trees/Acre	Density Trees/Hectare	Basal Area in^2 /Acre	Basal Area in^2 /HA
STAND 9					
Juniperus osteosperma	95	28	69	4284	6.8
Juniperus scopulorum	77.5	20	49	2360	3.7
Pinus edulis	60	17	42	1581	2.5
TOTAL		65	160	8225	13.1
STAND 13					
Juniperus osteosperma	62.5	18	44	2898	4.6
Juniperus scopulorum	62.5	27	67	3078	4.9
Pinus edulis	87.5	41	101	6847	10.9
Quercus gambelii	2.5	1	2	16	0.02
TOTAL		87	214	12839	20.4
STAND 12					
Juniperus osteosperma	5	1	2	82	0.1
Pinus edulis	100	104	257	4731	7.5
TOTAL		105	259	4813	7.6

Table V-39 SHRUB LAYER SPECIES COMPOSITION
FOR PINYON-JUNIPER WOODLAND EXPERIMENTAL SITE
(Stand #s 5-f and 5-o)
(VALUES BASED ON 20 2m X 10m SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Stand 5-f					
Amelanchier spp.	0.2	20	88	41.3	4
Artemisia tridentata	0.8	25	100	86.8	1
Cercocarpus montanus	0.4	30	150	68.3	2
Chrysothamnus nauseosus	<0.1	5	13	5.6	6
Juniperus osteosperma	<0.1	5	13	5.6	7
Pinus edulis	0.2	35	125	54.6	3
Purshia tridentata	<0.1	20	150	37.8	5
TOTALS	1.6		639		
Stand 5-0					
Amelanchier spp.	0.6	50	225	90.0	1
Artemisia tridentata	0.6	25	288	87.1	2
Cercocarpus montanus	<0.1	5	13	4.9	7
Juniperus osteosperma	<0.1	25	50	22.8	4
J. scopulorum	<0.1	10	13	7.9	6
Pinus edulis	1.2	50	13	76.5	3
Purshia tridentata	0.2	5	13	10.8	5
TOTALS	2.6		615		

Table V-40 SHRUB LAYER SPECIES COMPOSITION
FOR PINYON-JUNIPER WOODLAND CONTROL SITE
(Stand #s 6-o and 6-f)
(VALUES BASED ON 20 2m X 10m SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Stand 6-f					
Amelanchier spp.	<0.1	15	63	8.7	5
Artemisia tridentata	1.6	80	1475	185.8	1
C. viscidiflorus		5	13	2.5	6
Juniperus osteosperma	<0.1	40	150	25.4	3
Opuntia polyacantha	0.1	55	538	50.5	2
Pinus edulis	<0.1	45	150	24.6	4
Purshia tridentata	___	5	13	2.5	7
TOTALS	1.7		2402		
Stand 6-0					
Amelanchier spp.	0.4	40	200	42.1	2
Artemisia tridentata	1.6	70	1313	156.2	1
Chrysothamnus nauseosus	0.2	15	213	26.7	4
Juniperus osteosperma	<0.1	10	25	8.0	6
Opuntia polyacantha	0.1	45	325	41.1	3
Pinus edulis	0.3	20	38	22.9	5
Symphoricarpos oreophilus	<0.1	5	13	3.0	7
TOTALS	2.6		2127		

Table V-41 SHRUB LAYER SPECIES COMPOSITION
FOR PINYON-JUNIPER WOODLAND CONTROL SITE
(Stand #9)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	1.8	35	395	49.8	2
Cercocarpus montanus	<0.1	5	18	2.3	9
Chrysothamnus viscidiflorus	0.6	10	126	15.8	5
Juniperus osteosperma	0.2	25	108	14.8	6
J. scopulorum	<0.1	10	36	4.6	8
Opuntia polyacantha	<0.1	35	251	19.4	4
Pinus edulis	0.6	60	448	41.8	3
Purshia tridentata	3.6	90	2206	145.6	1
Symphoricarpos oreophilus	0.1	10	54	5.8	7
TOTALS	7.2		3642		

Table V-42 SHRUB LAYER SPECIES COMPOSITION
FOR PINYON-JUNIPER WOODLAND CONTROL SITE
(Stand #12)
(VALUES BASED ON 20 4 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	1.6	45	511	35.0	4
Artemisia tridentata	3.5	95	4545	113.1	1
Chrysothamnus viscidiflorus	0.3	85	2151	46.6	3
Juniperus osteosperma	0.5	5	27	7.5	7
Opuntia polyacantha	0.1	65	1050	28.3	5
Pinus edulis	2.1	65	860	49.6	2
Purshia tridentata	0.2	10	82	5.7	8
Symphoricarpos oreophilus	0.2	35	296	14.2	6
TOTALS	8.5		9522		

Table V-43 SHRUB LAYER SPECIES COMPOSITION
FOR PINYON-JUNIPER WOODLAND CONTROL SITE
(Stand #13)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	3.5	45	2,421	34.2	3
Artemisia tridentata	1.1	35	646	14.9	7
Cercocarpus montanus	1.8	60	1,022	24.9	4
Chrysothamnus nauseosus	0.1	20	90	4.9	11
C. viscidiflorus	0.9	45	520	15.7	6
Juniperus osteosperma	0.2	15	54	4.1	12
J. scopulorum	0.1	30	161	7.4	9
Pinus edulis	0.6	35	197	11.0	8
Purshia tridentata	2.3	45	1,022	23.5	5
Quercus gambelii	4.4	25	4,447	41.7	2
Ribes inerme	0.2	15	287	5.3	10
Rosa woodsii	0.1	5	305	2.5	13
Symphoricarpos oreophilus	9.0	85	14,489	113.9	1
TOTALS	24.3		25,661		

Table V-44 MATRIX OF SIMILARITY VALUES FOR SAMPLED
PINYON-JUNIPER WOODLAND STANDS

SIMILARITY VALUE

STAND NUMBERS	5–F	509	6–F	6–0	9	12	13
5–F	–	–	–	–	–	–	–
5–0	68.1	–	–	–	–	–	–
6–F	42.7	69.3	–	–	–	–	–
6–0	54.1	53.4	79.0	–	–	–	–
9	45.8	41.4	42.8	34.4	–	–	–
12	60.9	61.6	61.6	73.7	48.6	–	–
13	39.2	29.1	13.7	24.0	24.3	33.3	–

STAND NUMBERS

The average similarity includes comparision of open understory with dense understory stands. The only stand on the Tract with a dense understory is Stand 13. Recalculation of average similarity excluding data from this stand results in an average similarity of 56%. This suggests less heterogeneity among the open understory pinyon-juniper woodlands.

Stability, Diversity and Succession

The pinyon-juniper woodlands are one of the most stable plant communities in the region. Dendrochronological data show that the oldest trees are more than 200 years old and the largest trees are more than 2.5 feet (76 cm) in diameter; however, most of the trees are less than 30 feet tall. The pinyons and junipers do not appear to be invading other vegetation types. Saplings occur in the upland sagebrush communities, but establishment of individuals appears to occur intermittently. Herb diversity averages less than 10 species per quadrat which is an intermediate value compared with other plant communities.

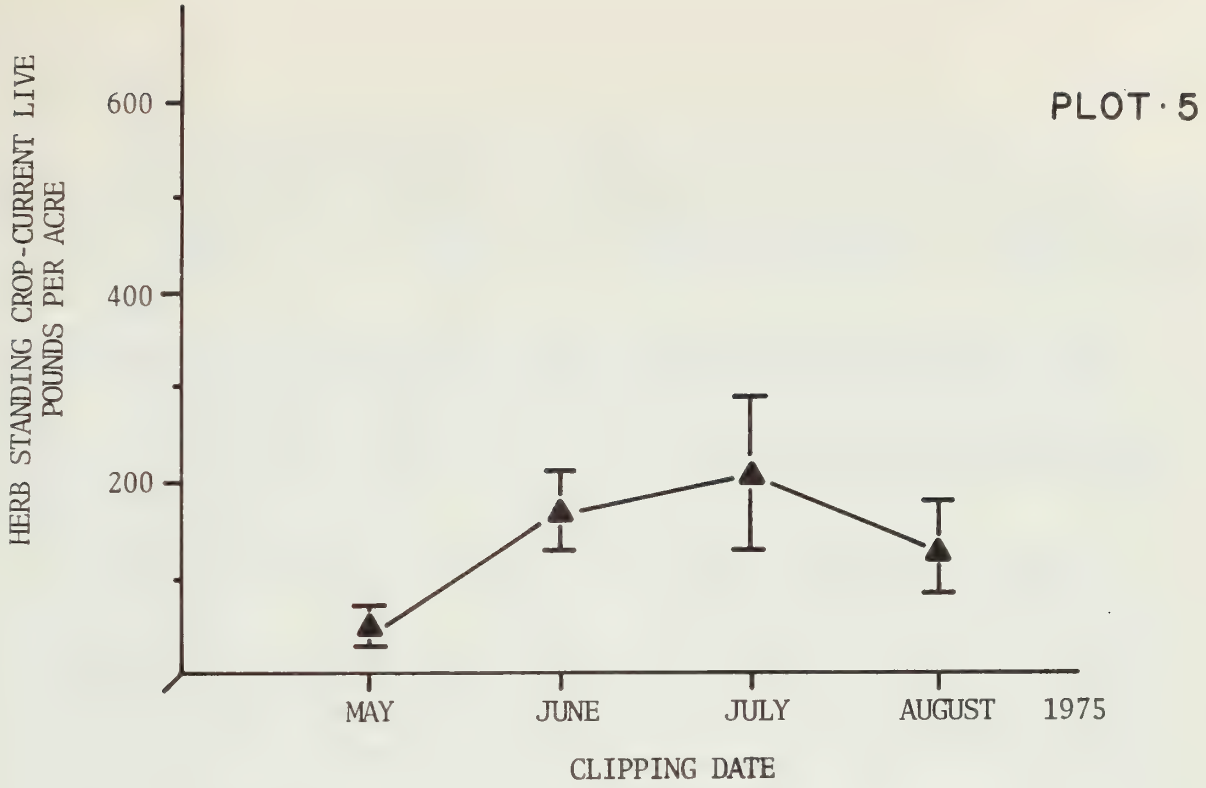
Productivity

Average herb production in the pinyon-juniper woodlands is approximately 240 $\pm$ 65 pounds per acre (Table V-35, Figure V-47). Production values are lower on hillside communities where May standing crop values are as low as 64 pounds per acre. Maximum values are reached in late July on hillside stands while on ridges maximum standing crop values occur in August. The productivity estimates for pinyon-juniper woodlands reflect the variation in the herbaceous vegetation. Bunchgrasses are common in these communities and the presence or absence of a single bunch in a clipping plot can substantially alter plot values. This effect is accentuated since the herbaceous vegetation between clumps is very sparse. Early in the season when the individual bunches are small, the differences among samples are not as great. As production peaks are reached later in the season, differences become more pronounced and the sample variance increases.

The lowest shrub production values obtained on the Tract were from the pinyon-juniper woodlands (221 pounds per acre per year, plots 5 and 6, Table V-36). The shrub component is made up of the same species which occur in the chained areas, however density values are lower. Competition between shrubs and trees for nutrients, light and moisture is probably a primary factor causing reduced shrub production in the woodlands. The shrub production in the chained areas is nearly four times greater than the production in the woodlands. Increase in shrub density, especially for big sagebrush, because of reduced competition with trees in the chained areas, is most likely the primary reason for the observed differences.

Environment

The pinyon-juniper woodlands are developed mostly on Redcreek and Rentsac channery soils. These soils tend to be thin and are developed over fractured or non-fractured sandstone bedrock. While these soils have adequate levels of nitrogen, they tend to have low or deficient potassium and phosphorus concentrations.



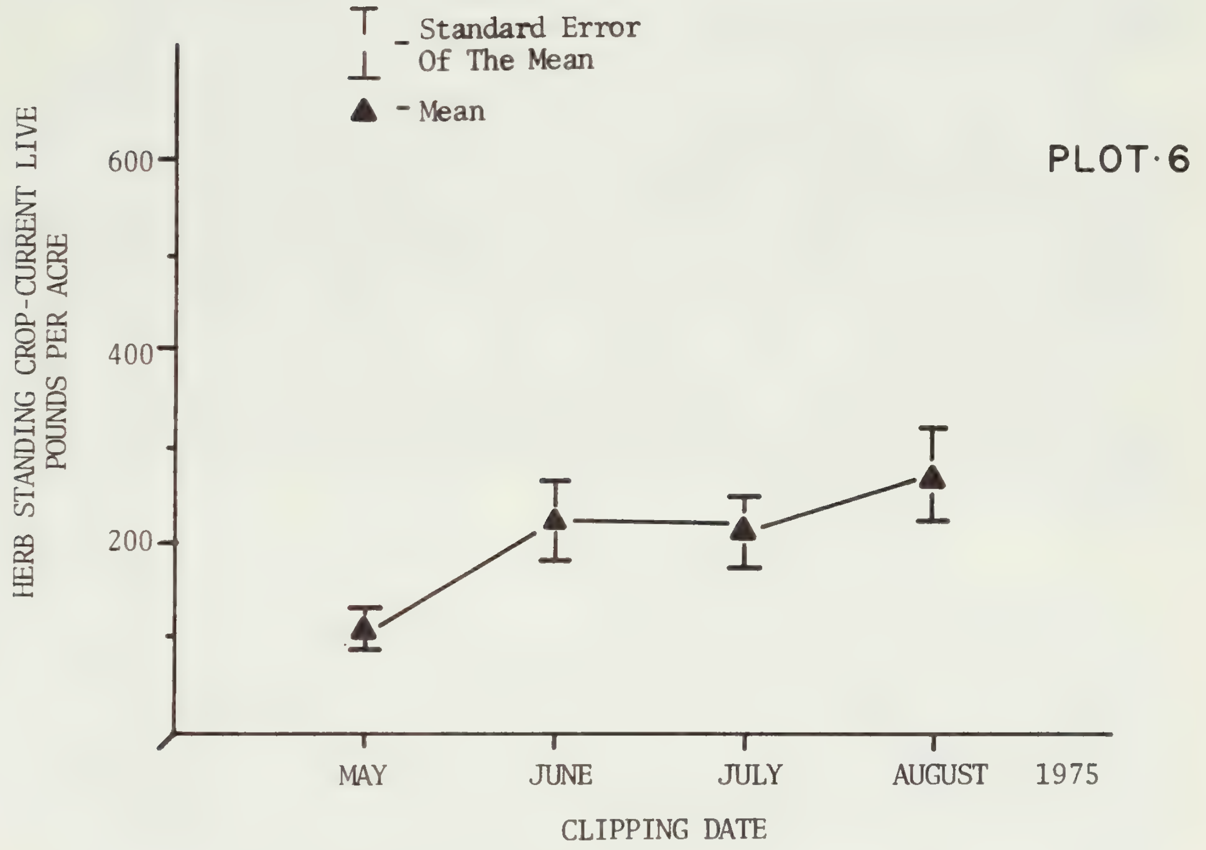


Figure V-47 CHANGES IN HERBACEOUS STANDING CROP, PINYON-JUNIPER WOODLAND, 1975

Precipitation values for the Tract are highly variable. Preliminary analysis of data (see below) shows little indication of precipitation patterns with elevation, topography or vegetation types. Most of the precipitation falling in the woodlands either moistens the surface soil layers, evaporates or sublimates in the case of snow. Runoff is minimal.

Temperature profiles constructed for the four major vegetation types (Chapter VII) show that pinyon-juniper woodlands are the coldest sites. This relationship is true of the entire temperature profile. Effective solar radiation is decreased by canopy cover. This effect is augmented in winter by snow pack.

Soil moisture values fluctuate considerably throughout the season. Values are high in the spring and drop to levels as low as 20% on some sites by September (Table V-37).

Fires occasionally occur in the pinyon-juniper woodlands. Several burned sites can be found from one fire in the northeast portion of the area between lower Stewart Gulch and Piceance Creek. This fire caused complete destruction of the woodland. Several charred trees remain standing but most have fallen. Few saplings occur in the area, and the most abundant species is Indian ricegrass. Fires are probably not common since the open canopy and sparse understory do not provide the fuel necessary for frequent fires.

Current Land Use and Management

The pinyon-juniper woodlands are used as livestock grazing areas during late spring, summer and early fall. In mid-summer most of the cattle have moved to higher elevations and are not found on the Tract. Maximum grazing use occurs in May and October when the livestock are being moved from lower-valley winter range to and from native upland ranges.

Large areas of the Tract woodlands have been chained as part of a range improvement program. By removing the trees, production in herb and shrub layers have been stimulated, thus increasing available forage. After the trees were removed, range grasses were seeded in order to increase grass production.

(ii) Chained Pinyon-Juniper Rangeland

General Location and Distribution

The chained rangelands constitute a highly variable and somewhat artificial plant community. This vegetation type has been produced through management practices of the BLM and its distribution is determined by BLM selection of chaining sites. Chaining is mostly restricted to ridges and gentle hillsides where it is possible to operate the bulldozers necessary for the chaining operation. On the Tract the chained rangelands occur primarily in the central portion of the study area and cover approximately 45% of the Tract.

Structure and Composition

The general appearance of the chained rangelands is that of a shrubland with many fallen trees. Total shrub density is approximately 4750 individuals per hectare and shrub cover averages 11%. The dominant species include big sagebrush, bitterbrush and saplings of pinyon pine and Utah juniper. In some location snowberry occurs as a dominant species but it tends to be locally abundant rather than occurring as a widespread dominant (Tables V-45, -46, -47, -48, -49, -50 and -51).

Since chaining in 1966, the pinyons and junipers have made some recovery. Average sapling densities for these two species were 324 pines per hectare and 260 junipers per hectare.

Cover by herbs in the chained rangelands averages 32% which is approximately twice the value in pinyon-juniper woodlands. Three perennial grass species are common: Indian ricegrass, squirreltail grass and western wheatgrass. Many annual species also occur including cheatgrass, goosefoot, stickseed and tansy mustard, but cheatgrass is the most common (Tables V-33 and V-34, Stands 1-0, 1-F, 2-0, 2-F, 7, 10 and 11).

Stability, Diversity and Succession

The chained rangelands constitute ecologically unstable communities. Destruction of the woodlands has greatly altered the original vegetation and has initiated successional changes which will contine until the woodlands become re-established. The observed variation within the chained woodland areas results from original differences in the woodlands and also from differential successional rates. Where environmental factors are more favorable, successional rates will be greater. The heterogeneity is reflected in the average similarity among all sampled stands (53.4%, Table V-52). The fact that this value is somewhat higher than the average value for pinyon-juniper woodland most likely reflects the lack of chained sites on north-facing slopes. The intensive study (permanent) sites are 50% similar to the other sampled chained sites.

Successional changes within these communities will take place slowly. It may take as long as 200 years for these sites to return to a woodland vegetation.

Production

Herb shoot production in the chained rangelands averages 459 ± 141 pounds per acre per year. Standing crop values average 125 pounds per acre in May and reach maximum values in July. The pattern of increasing herb variation later in the gowing season, characteristic of pinyon-juniper woodlands, is also apparent in the chained pinyon-juniper rangelands (Table V-35, Figure V-48). Production in the chained rangelands shows that greatest variation of any of the vegetation types and is the second most productive in terms of herby standing crop.

Table V-45 SHRUB LAYER SPECIES COMPOSITION FOR
CHAINED PINYON-JUNIPER RANGELAND EXPERIMENTAL SITE
(Stand #1-f)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	0.6	15	38	7.9	9
Artemisia tridentata	5.3	80	1600	135.6	1
Cercocarpus montanus	0.1	50	250	24.6	4
Chrysothamnus nauseosus	1.4	50	275	39.8	2
C. viscidiflorus		5	13	1.9	11
Gutierrezia sarothrae	0.5	15	75	12.6	6
Juniperus osteosperma	0.2	25	63	11.9	7
J. scopulorum	<0.1	5	13	1.9	12
Opuntia polyacantha		10	125	7.3	10
Pinus edulis	0.2	25	163	15.9	5
Purshia tridentata	0.6	50	275	31.0	3
Symphoricarpos oreophilus	0.1	20	75	9.6	8
TOTALS	9.1		2965		

Table V-46 SHRUB LAYER SPECIES COMPOSITION FOR
CHAINED PINYON-JUNIPER RANGELAND EXPERIMENTAL SITE
(Stand #1-o)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	0.3	40	188	14.8	5
Artemisia tridentata	9.6	100	2788	147.8	1
Cercocarpus montanus	0.4	65	350	24.7	3
Chrysothamnus nauseosus	0.4	30	188	13.3	7
C. viscidiflorus		5	13	1.4	11
Gutierrezia sarothrae	< 0.1	5	13	1.4	12
Juniperus osteosperma	0.6	40	100	14.6	6
J. scopulorum	1.0	5	25	8.2	9
Opuntia polyacantha		20	100	6.4	10
Pinus edulis	0.8	55	263	23.1	4
Purshia tridentata	1.2	65	525	33.6	2
Symphoricarpos oreophilus	0.2	30	150	10.7	8
TOTALS	14.6		4703		

Table V-47 SHRUB LAYER SPECIES COMPOSITION FOR
CHAINED PINYON-JUNIPER RANGELAND CONTROL SITE
(Stand #2-f)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	<0.1	30	100	15.9	6
Artemisia tridentata	1.1	35	250	37.4	4
Cercocarpus montanus	0.4	10	63	11.1	7
Chrysothamnus nauseosus	0.6	50	225	36.0	5
C. viscidiflorus	<0.1	5	0	1.6	9
Juniperus osteosperma	2.8	70	413	76.7	1
Opuntia polyacantha	<0.1	10	50	6.1	8
Pinus edulis	1.2	65	288	49.8	3
Purshia tridentata	3.2	35	350	65.4	2
TOTALS	9.6		1739		

Table V-48 SHRUB LAYER SPECIES COMPOSITION FOR
CHAINED PINYON-JUNIPER CONTROL SITE
(Stand #2-o)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	0.2	20	75	14.0	7
Artemisia tridentata	0.3	50	188	31.3	4
Cercocarpus montanus	0.3	25	50	15.5	6
Chrysothamnus nauseosus	2.6	85	363	93.5	1
C. viscidiflorus	<0.1	5	13	2.2	10
Gutierrezia sarothrae	<0.1	5	13	2.2	11
Juniperus osterosperma	1.3	50	213	51.3	2
Opuntia polyacantha		35	125	17.7	5
Pinus edulis	0.8	65	288	50.2	3
Purshia tridentata	<0.1	20	100	11.9	8
Symphoricarpos oreophilus	<0.1	10	100	10.2	9
TOTALS	5.9		1528		

Table V-49 SHRUB LAYER SPECIES COMPOSITION FOR CHAINED PINYON-JUNIPER RANGELAND
(Stand #7)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	1.4	20	377	18.5	4
Artemisia tridentata	4.6	80	2528	78.5	2
Cercocarpus montanus	0.1	35	430	13.9	6
Chrysothamnus nauseosus	0.2	15	72	5.9	11
C. viscidiflorus	<0.1	25	126	7.5	9
Juniperus osteosperma	0.9	55	341	23.3	3
Opuntia polyacantha	0.2	45	466	17.5	5
Pinus edulis	0.2	35	251	12.6	7
Purshia tridentata	0.6	20	179	11.0	8
Quercus gambelii	0.4	5	287	7.1	10
Symphoricarpos oreophilus	6.1	75	4035	104.2	1
TOTALS	14.8		9092		

Table V-50 SHRUB LAYER SPECIES COMPOSITION FOR CHAINED PINYON-JUNIPER RANGELAND
(Stand #10)
(VALUES BASED ON 20, 6 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	0.1	15	179	9.9	5
Artemisia tridentata	3.8	60	3658	124.5	1
Chrysothamnus nauseosus	0.4	10	72	9.0	7
C. viscidiflorus	<0.1	5	18	2.3	10
Juniperus osteosperma	0.3	30	126	16.6	4
J. scopulorum	0.1	15	54	7.9	8
Opuntia polyacantha	<0.1	10	72	6.2	9
Pinus edulis	0.6	45	269	28.9	3
Purshia tridentata	3.8	50	1542	86.5	2
Symphoricarpos oreophilus	0.1	15	179	9.9	6
TOTALS	9.4		6169		

Table V-51 SHRUB LAYER SPECIES COMPOSITION FOR CHAINED PINYON-JUNIPER RANGELAND
(Stand #14)
(VALUES BASED ON 20, 4 FT. X 50 FT. SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	1.1	45	860	31.3	4
Artemisia tridentata	<0.1	10	54	3.2	9
Cercocarpus montanus	3.2	55	808	49.1	2
Chrysothamnus nauseosus	<0.1	5	27	1.6	10
Chrysothamnus viscidiflorus	0.3	50	618	22.9	6
Juniperus osteosperma	1.0	55	566	29.2	5
Opuntia polyacantha	<0.1	5	27	1.6	11
Pinus edulis	1.2	75	753	38.3	3
Purshia tridentata	1.2	20	296	17.9	7
Symphoricarpos oreophilus	5.2	80	2905	100.9	1
Tetradymia canescens	<0.1	10	109	4.0	8
TOTALS	13.6		7023		

Table V-52 MATRIX OF SIMILIARITY VALUES FOR SAMPLED CHAINED RANGELAND STANDS

SIMILARITY VALUE

STAND NUMBERS	1–F	1–0	2–F	2–0	7	10	14
1–F	–	–	–	–	–	–	–
1–0	87.0	–	–	–	–	–	–
2–F	52.0	51.8	–	–	–	–	–
2–0	51.0	59.5	71.1	–	–	–	–
7	53.5	56.6	38.9	47.3	–	–	–
10	73.3	80.0	58.2	41.9	51.0	–	–
14	32.0	37.8	40.1	42.6	64.7	30.6	–

STAND NUMBERS

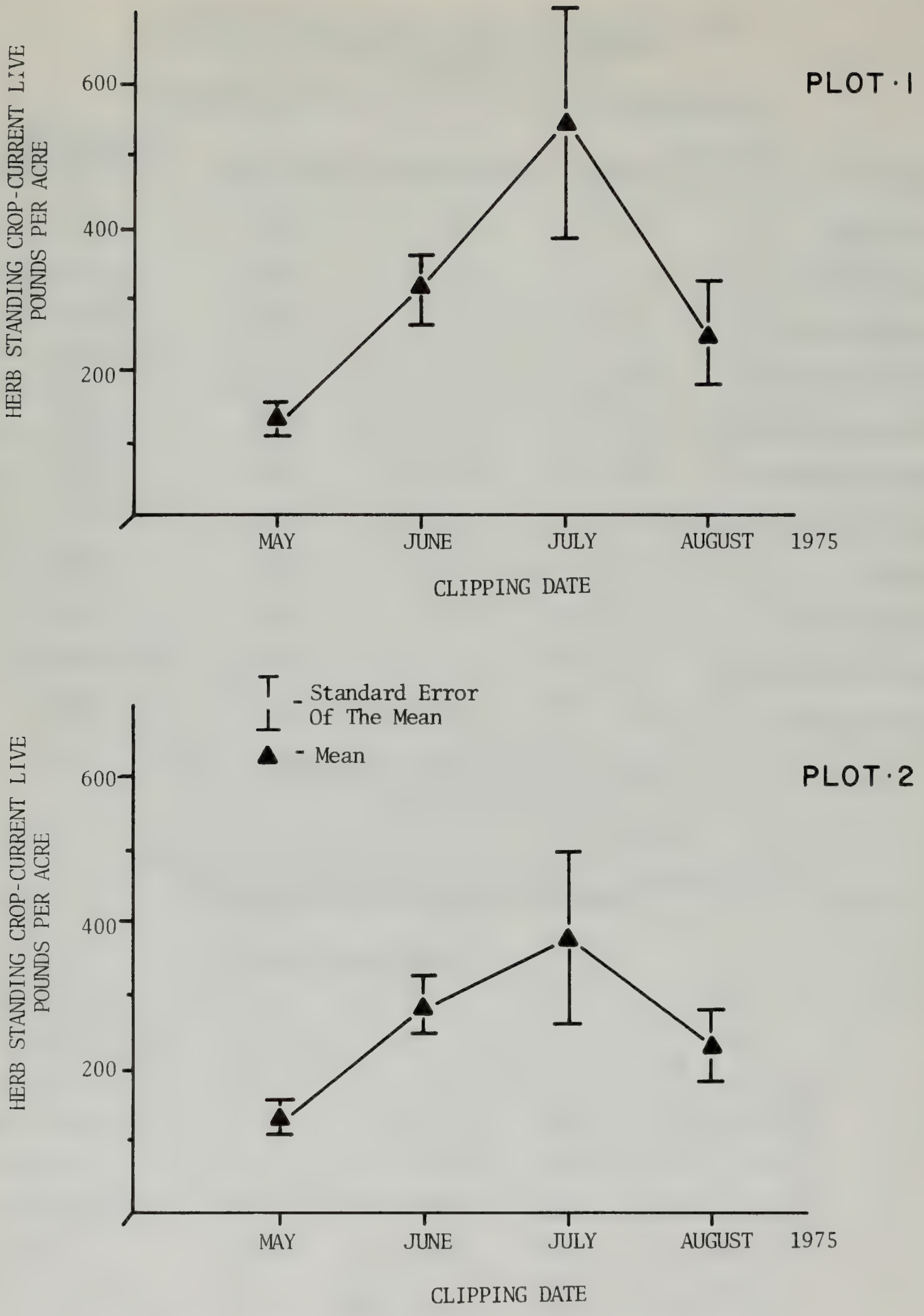


Figure V-48 CHANGES IN HERBACEOUS STANDING CROP, CHAINED PINYON-JUNIPER RANGELANDS, 1975

Shrub production in the chained areas was nearly as great as the production in the upland sagebrush sites and averaged 854 pounds per acre per year. Production from site to site is variable in the chained areas (Plots 1 and 2, Table V-36) and major differences result primarily from differences in sagebrush densities. Where sagebrush densities are high, total shrub production is also high. Other shrub species appear to be more evenly distributed.

Environment

Soils in the chained rangelands have essentially the same characteristics as in the pinyon-juniper woodlands. However, other environmental factors have been altered as a result of chaining. Solar radiation is much more uniform in the chained areas because of the absence of a tree canopy. Radiation intensities are reduced under the fallen timber; however, these conditions are different from those produced by a vegetation canopy.

Chained sites are the warmest sites of the four vegetation types on Tract C-b during cool weather (Chapter VII). Differences in temperature between extremes in depth and height are the greatest of all sites. The behavior of the temperature profile is markedly similar to that of the woodland sites. The extreme difference in actual mean temperature between the chained areas and the woodland sites is due to the absence of canopy cover in the former type.

Snow distributional patterns have been altered as a result of chaining. Snow tends to collect in the lee side of the windrows of fallen trees, thus producing an effect on the distribution of soil moisture.

Fires could occur within the chained areas and the fallen timber would supply an abundance of fuel. To date, however, no evidence of fire has been observed in these areas.

Current Land Use and Management

Currently the chained rangelands are used for cattle grazing. Since chaining, no further management practices have been employed in this vegetation type.

Additionally, these sites are used as firewood cutting areas under permits issued by the BLM. Woodcutters selectively remove trunks and larger branches, but leave behind tree bases, roots and smaller branches.

Big Sagebrush

Big sagebrush are widely distributed throughout the Piceance Basin and occur as two structurally different types. On lower valley floors and on alluvial fans big sagebrush occurs at very high densities and attains heights in excess of 3 meters. Big sagebrush also occurs in nearly pure stands on ridges and as clearings in the pinyon-juniper woodlands. On these sites the sagebrush is much smaller in stature and

does not reach densities as great as those attained in the valley communities. The ridgetop communities extend to elevations as great as 8,500 feet. Variation in the size and density of sage plants in the valleys results from the number of environmental parameters as well as possible genetic sub-specific differences. The upland sagebrush sites occur primarily on Forelle and Piceance loam soils which are generally characterized by low or deficient phosphorus and potassium concentrations. The bottomland sagebrush stands, however, occur on Glendive and Hanly loam soils which are characterized by normal, high or excessive amounts of these same nutrients. These sites also contain high to excessive amounts of sulfate. Differences in sagebrush size may well result from differing concentrations of these major plant nutrients. Additionally, the effect of total salt concentration may be playing an important role in causing sagebrush community differences. Total salts tend to be excessive in the valleys and low on the uplands. Soil moisture values for March through October averaged 43% in the upland sagebrush sites and only 32% in the bottomland sites (Table V-37). These differences may result from differences in soil texture; Piceance and Forelle loams tend to have higher clay content and better water retaining characteristics. The higher soil moisture levels on the ridges are important for the growth and development of the numerous herbaceous species which characterize the upland sites.

(iii) Upland Sagebrush Communities

General Location and Distribution

Within the Tract study area upland sagebrush communities occur on broad ridgetops and in clearings within the pinyon-juniper woodlands. This community type usually does not develop on sloping sites.

Structure and Composition

The dominant species in the upland sagebrush communities is big sagebrush which occurs at an average density of 10,500 individuals per hectare. Other shrub species are relatively unimportant in these communities. Saplings of pinyon pine and juniper commonly occur, but density values for these species are low. Prickly pear (*Opuntia polyacantha*) is a common shrub layer component on many of the upland sagebrush types. (Tables V-53 through V-56).

The herb layer is composed of many species which occur at high frequencies. Western wheatgrass, Junegrass, long-leaved phlox, false dandelion, mariposa lily, *Trifolium gymnocarpon* and *Microsteris micrantha* are all common species which occur at nearly 100% frequency. (Tables V-33 and V-34, Stands 3-0, 3-F, 8, 11 and 15). Cover by herbs in these communities averages 45%. Mosses and lichens occur only around the bases of the individual sagebrush plants where accumulation of litter and moisture from snow and branch runoff provide suitable habitat.

The upland sagebrush sites are quite homogeneous. The average similarity value based on shrub importance values among all sample

Table V-53 SHRUB LAYER SPECIES COMPOSITION FOR UPLAND SAGEBRUSH COMMUNITY
(Stand #s 3-f and 3-o)
(VALUES BASED ON 20 2m X 10m SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Stand 3–F					
Artemisia tridentata	5.2	100	7050	243.6	1
Gutierrezia sarothrae	<0.1	15	63	8.7	4
Juniperus osteosperma	0.1	5	13	2.8	5
Opuntia polyacantha	<0.1	55	288	32.8	2
Pinus edulis	0.2	15	38	12.1	3
TOTALS	5.4		7452		
Stand 3–0					
Amelanchier spp.	<0.1	40	150	16.8	3
Artemisia tridentata	10.0	100	8500	224.8	1
Chrisothamnus nauseosus	0.1	10	25	5.0	6
C. viscidiflorus	<0.1	5	13	2.0	7
Gutierrezia sarothrae	<0.1	40	100	16.7	4
Opuntia polyacantha	<0.1	35	100	14.8	5
Pinus edulis	0.6	35	113	19.9	2
TOTALS	10.7		9001		

Table V-54 SHRUB LAYER SPECIES COMPOSITION FOR UPLAND SAGEBRUSH COMMUNITY
(Stand #8)
(VALUES BASED ON 20, 6 X 50 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	17.7	100	13,736	247.3	1
Chrysothamnus nauseosus	0.2	10	144	7.5	5
C. viscidiflorus	< 0.1	10	72	5.9	6
Juniperus osteosperma	0.4	15	108	10.9	3
Opuntia polyacantha	< 0.1	35	144	19.8	2
Pinus edulis	< 0.1	15	72	8.6	4
TOTALS	18.6		14,276		

Table V-55 SHRUB LAYER SPECIES COMPOSITION FOR UPLAND SAGEBRUSH COMMUNITY
(Stand #11)
(VALUES BASED ON 20, 6 X 50 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	<0.1	5	72	2.6	6
Artemisia tridentata	17.4	100	13,539	235.9	1
Juniperus osteosperma	0.1	15	54	7.1	4
J. scopulorum	<0.1	15	72	6.9	5
Opuntia polyacantha	0.2	50	359	24.9	2
Pinus edulis	0.2	45	179	21.5	3
Symphoricarpos oreophilus	<0.1	5	18	2.2	7
TOTALS	18.2		14,293		

Table V-56 SHRUB LAYER SPECIES COMPOSITION FOR UPLAND SAGEBRUSH COMMUNITY
(Stand #15)
(VALUES BASED ON 20 4 X 50 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Amelanchier spp.	3.9	100	2823	49.2	3
Artemisia tridentata	18.1	100	9710	133.8	1
Chrysothamnus viscidiflorus	1.2	95	8151	58.8	2
Opuntia polyacantha	<0.1	10	81	2.6	7
Pinus edulis	<0.1	30	242	7.7	5
Purshia tridentata	<0.1	5	27	1.2	8
Symphoricarpos oreophilus	1.9	85	3767	41.6	4
Tetradymia canescens	<0.1	20	133	5.0	6
TOTALS	25.5		24934		

stands was 74% (Table V-57). The permanent study sites (Stands 3-0 and 3-f) have an average of 79% similarity with other upland sites. Values greater than 80% indicate high vegetational similarity. Some of the upland sites are more than 90% similar.

Stability, Diversity and Succession

The upland sagebrush communities on the Tract constitute an ecologically-stable vegetation type. Several observations point to the long standing presence of this vegetation unit. Herb diversity in these communities is high (14.1 species per square meter). In this region it appears that considerable time periods are required for species diversity to reach this level. Factors other than time are also important in determining diversity but the herb complexity in this vegetation type certainly suggests long-term stability. The growth of sagebrush is such that it is possible to determine approximate ages by counting growth rings in stem cross-sections. The ages obtained for ridgetop plants represent minimal estimates since the plants are multiply-stemmed and as older stems die, new shoots develop. The older sagebrush stems are approximately 50 years old. In addition sagebrush plants are represented in all size classes; this suggests an equilibrium state with local environmental conditions.

These sagebrush stands are not successional. In some places pinyon and juniper saplings occur; however, density values for these species are low and suggest only occasional successful establishment. At higher elevations there is a greater component of mixed mountain shrubland species in the sagebrush communities.

Productivity

The herbaceous plants in the upland sagebrush sites begin growth in mid-to-late-April and by mid-May herb standing-crop values are approximately 300 pounds per acre. Total current live standing-crop increases during June and reaches a maximum value of 560 pounds per acre in mid-July. Plants begin senescing after this date and total standing-crop decreases to approximately 400 pounds per acre in August (Figure V-49, Table V-35). Next to the chained rangeland sites these communities have the greatest herb-layer production. Production is more uniform on a unit area basis here than in other communities. The presence of western wheatgrass and Junegrass as dominant species rather than bunchgrasses reduces the between-plot variance characteristic of the other vegetation types.

Shrub production in the upland sagebrush communities was much less than that in the bottomland communities (979 pounds per acre vs 7776 pounds per acre) (Plot 3, Table V-36). Big sagebrush density and yearly stem-weight increases are lower in the upland sites. Several other species occur along with sagebrush but most of the production is attributable to sagebrush.

Table V-57 MATRIX OF SIMILARITY VALUES FOR SAMPLED UPLAND SAGEBRUSH STANDS

SIMILARITY VALUE

STAND NUMBERS	3–F	3–0	8	11	15
3–F	–	–	–	–	–
3–0	86.8	–	–	–	–
8	91.6	85.1	–	–	–
11	91.9	87.4	90.5	–	–
15	48.0	54.3	50.3	52.0	–

STAND NUMBERS

Table V-58 SHRUB LAYER SPECIES COMPOSITION FOR BOTTOMLAND SAGEBRUSH COMMUNITY
(Stand #s 4-f and 4-o)
(VALUES BASED ON 20, 6' X 50' SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	29.6	100	16,875	232.8	1
Chrysothamnus nauseosus	<0.1	10	50	5.6	3
Ceratoides lanata	1.8	70	2,588	55.9	2
Opuntia polyacantha	<0.1	5	88	3.0	4
Purshia tridentata	<0.1	5	13	2.7	5
TOTALS	31.7		19,614		
Artemisia tridentata	36.8	100	22,513	258.1	1
Chrysothamnus nauseosus	<0.1	15	63	9.4	4
Ceratoides lanata	0.1	15	213	10.3	3
Opuntia polyacantha	0.2	35	125	22.2	2
Purshia tridentata	<0.1	0	0	0.0	5
TOTALS	37.3		22,914		

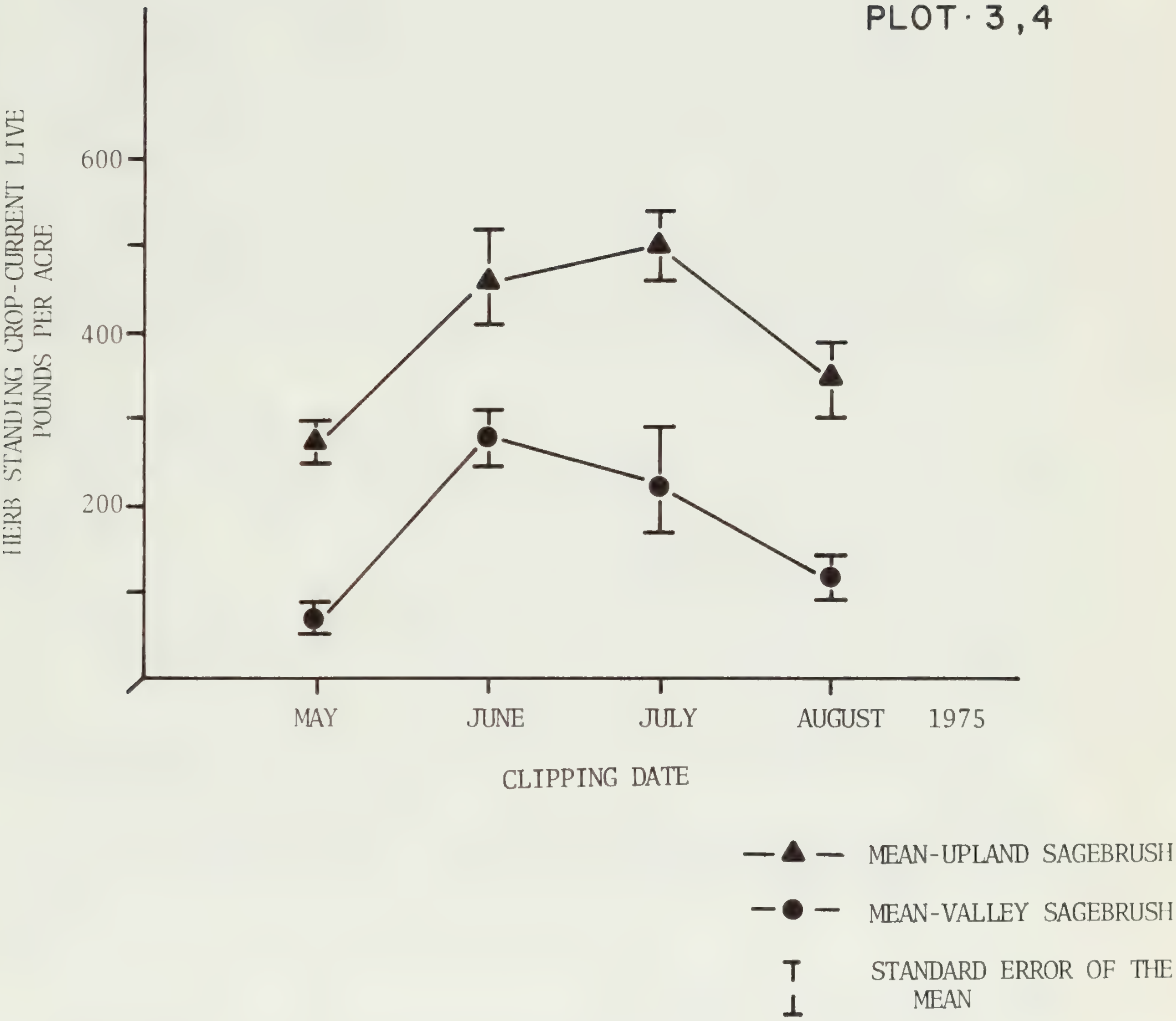


Figure V-49 CHANGES IN HERBACEOUS STANDING CROP, BIG SAGEBRUSH COMMUNITIES, 1975

Environment

The important features of the soil characteristics within this vegetation type have been mentioned above.

The temperature profile for this community type shows more vertical mixing than do the other three major vegetation types. This is reflected by the small differences in temperature at the surface and in free air one meter above the surface. This relationship appears to be the result of the low profile of the vegetation which has little retardant effect on circulating air. In contrast the remaining community types display structural features which channel and buffer moving air. Temperatures in upland sagebrush communities are intermediate with respect to the remaining three vegetation types. The greater response of soils at depth is the apparent result of fine-textured soils in combination with good vertical mixing in the air immediately above the surface.

Snow accumulation is important in this community as a source of soil moisture. During the winter snow accumulates to a depth approximately equal to the height of the shrubs. As the snow melts in spring, most of the moisture penetrates into the soil and very little runs off. Because of the deep nature of the loamy soils, soil moisture conditions remain favorable throughout the growing season.

Fires occur occasionally in the upland sagebrush communities. Sites most likely to burn are those which occur as clearings within the woodlands. The incidence of fire is not frequent enough to suggest that it is the factor governing the distribution of this vegetation type.

Current Land Use and Management

The upland sagebrush areas are used for livestock grazing. Cattle utilize these areas mostly in May and early June and again in late September and early October. During the major part of the growing season the cattle graze at higher elevations.

Various management techniques have been used in the upland sagebrush communities. Some of the upland sites were chained along with the pinyon-juniper woodlands. The sagebrush does not appear to have been greatly affected by this management approach. No other management practices have been used in the upland sagebrush communities.

(iv) Bottomland Sagebrush Communities

General Location and Distribution

The bottomland sagebrush communities typically occur in the valley floors and alluvial fans of the gulches throughout the Piceance Creek basin. The larger valleys which contain intermittent streams usually are dominated by this vegetation type. Stands of bottomland sagebrush occur at the mouths of most of the small gulches which feed into the major drainages. Narrow strips of sagebrush vegetation follow the intermittent stream channels into the small draws.

Within the Tract study area, the best developed areas of bottomland sagebrush occur in Scandard Gulch and along West Fork Stewart Creek.

Structure and Composition

The overwhelmingly dominant species in these communities is big sagebrush which provides an average cover of 37% and occurs at an approximate density of 1800 individual plants per hectare (Tables V-58 through V-60). Prickly pear and winter fat also occur but have low cover and density values. Winter fat reaches its greatest cover and density in the big sagebrush communities. Other shrub species may be encountered in these communities but they comprise a minor component of the vegetation. Density of sagebrush in the bottomlands is 1.7 times greater than on the uplands.

The herb layer in the bottomland sagebrush communities is very different from that in the upland communities. The dominant species are cheatgrass, goosefoot, stickseed and mountain peppergrass which are all characteristic of disturbed sites. The first three species are annuals. Cheatgrass occurs at an average frequency of 100% in the four sampled bottomland sagebrush stands (Tables V-33 and V-34, Stands 4-O, 4-f, 16 and 19). The most common perennial species was western wheatgrass.

Stability, Diversity and Succession

The widespread distribution and internal homogeneity of this vegetation type suggest its long-term presence in regional vegetation dymanics. All sizes (age classes) of big sagebrush plants occur within the stands (seedlings as well as old, fallen, decomposing stems). The oldest plants (estimated ages based on growth ring counts) are approximately 70 years old. Based on shrub importance value, the average similarity among sampled bottomland sagebrush stands is 84.5% (Table V-61). Some of the similarity values between stands are in the range of 90%, which suggests a very homogeneous vegetation type. Average similarity between the permanent study sites and other bottomland sagebrush stands was approximately 84%.

Apparently, the high salt concentrations which characterize the soil in these communities are detrimental to the development of a diverse understory. Herby diversity averages only 4.8 species per square meter, compared with 14.1 species per square meter in the upland sagebrush communities.

The bottomland sagebrush community is not successional and shows no strong developmental relationship coincident with settlement by early ranches in the late 1800's. Agricultural disturbances within these communities seem to favor the development of communities dominated by rabbitbrush rather than by big sagebrush.

Productivity

Herb production in the bottomland sagebrush results primarily from the growth of annual species, primarily cheatgrass. Maximum standing

Table V-59 SHRUB LAYER SPECIES COMPOSITION FOR BOTTOMLAND SAGEBRUSH COMMUNITY
(Stand #16)
(VALUES BASED ON 20, 6 X 50 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	40.8	100	15,278	225.6	1
Chrysothamnus nauseosus	4.4	55	2,242	49.8	2
Opuntia polyacantha	0.1	30	215	16.4	3
Symphoricarpos oreophilus	.1	15	108	8.2	4
TOTALS	45.4		17,843		

Table V-60 SHRUB LAYER SPECIES COMPOSITION FOR BOTTOMLAND SAGEBRUSH COMMUNITY
(Stand #19)
(VALUES BASED ON 20, 6 X 50 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	38.9	100	17,502	261.8	1
Chrysothamnus nauseosus	2.5	30	502	30.	2
Opuntia polyacantha	.1	10	72	7.	3
TOTALS	41.5		18,076		

Table V-61 MATRIX OF SIMILARITY VALUES FOR SAMPLED BOTTOMLAND SAGEBRUSH STANDS

SIMILARITY VALUE

STAND NUMBERS	4–F	4–0	16	19
4–F	–	–	–	–
4–0	84.9	–	–	–
16	78.1	83.8	–	–
19	80.5	91.7	87.7	–

STAND NUMBERS

crop is attained in June (one month earlier than in upland sagebrush communities) and net shoot production is only 56% as great as in upland sites (278 pounds dry weight per acre). Herb standing crop values start low in May (71 pounds dry weight per acre) and increase rapidly to maximum values in June. This growth pattern is very characteristic of cheatgrass which matures and begins to senesce by early July. Standing crop values decrease after June maximums, and by August current live values are only 120 pounds dry weight per acre (Table V-35, Figure V-49). Late season, current live values result mostly from western wheatgrass, a perennial, which matures later in the season.

The bottomland sagebrush communities are the most productive shrub communities within the study area. Production by big sagebrush was nearly 7800 pounds per acre for the valley site (plot 4, Table V-36). High values in these communities result from not only the yearly increase in plant weight, but also from the very high sagebrush densities which characterize this vegetation type. Very few other shrub species grow in these communities and those which do occur are relatively unimportant in terms of shrub production. Winter fat (Ceratoides lanata) is a species of interest in the bottomland sagebrush communities. Estimates of production by this species were judged to be inadequate since standing crop estimates in April were greater than those in September. In April nearly all of the winter fat plants had been clipped to ground level and had apparently been eaten by either rabbits or rodents. The only plants which were easily found were the larger ones. Entire plants were cut at ground level and returned to the lab for drying. In September the new growth on the plants made them much more visible and even those individuals with only one or two stems were easily seen. The dry weights of this sample produced total standing-crop estimates less than those in April. Although the total energy flow through this species is small compared with big sagebrush, it appears that an adquate estimate is important for evaluating the role which this species plays as a winter food source for some of the smaller mammals within the bottomland sagebrush communities.

Environment

The importance of soil nutrients and soil moisture in these plant communities was previously discussed. Other environmental factors are probably less important in determining the distribution of this vegetation type.

The unique feature of this vegetation type is the unusual variation of subsurface temperatures with depths (Chapter VII). This type displays a perturbation at depth so that the extreme subsurface is colder than shallow soil areas during both warm and cold weather. This differs from the characteristic pattern of gradual temperature decrease with soil depth in warm weather and the gradual increase of temperature with depth in cold weather. In this vegetation type, the shallow soil areas are either warmer than the surface or about the same temperature. The probable mechanism responsible for this phenomenon is the poor mixing of air above the surface. This effect is produced by dense vegetation which is more than one meter in height in combination with adequate heating of the fine-textured soils.

The lower average air temperatures at one meter, in contrast to upland sagebrush stands, are the result of cold air drainage in bottomland sites. Apparently, the vegetation height is responsible for limiting the effects of cold air drainage to the level of the shrub crown.

Fire probably occurs periodically in the bottomland; however, it does not play an important role in this community type. It is possible that fire may have been used to clear portions of valley bottoms during settlement days since sagebrush is intolerant of burning.

Current Land Use and Management

The valley sagebrush communities are currently used for livestock grazing. Cattle utilize the areas in spring and fall but during summer most of the cattle are found at elevations higher than the Tract.

Some of the bottomland sagebrush stands have been sprayed with herbicide in order to eliminate the sagebrush and encourage the growth of forage species. Most of this activity has occurred on private land outside the Tract boundaries but within the study area. Spraying successes vary and on some sites sagebrush kill has been nearly complete (along Willow Creek). Rabbitbrush appears to be more tolerant of the herbicide and has assumed a dominant role on some sprayed sites.

(v) Douglas-fir Forests

General Location and Distribution

The Douglas-fir forests are a common vegetation type at higher elevations in the Piceance Creek Basin. In the southern portion of the basin they occur primarily on north-facing slopes and individual forests may cover many areas. In the northwestern portion of the basin stands of Douglas-fir are much less common and in this region the north-facing sites are dominated by aspen. Transitional stands exist in which both aspen and Douglas-fir are greatly restricted and the stands that occur are usually composed of only a few trees. Aspen does not occur at the lower elevations.

In the Tract study area small isolated stands of Douglas-fir occur in the draws on the south side of Piceance Creek valley and also to a lesser extent in the small draws which drain into West Fork Stewart Creek. In only one or two locations is the tree density great enough to form true forest conditions.

Structure and Composition

The stands of Douglas-fir which occur on the Tract are composed of only a few scattered trees. The stand near the mouth of Sorghum Gulch is a typical example of this vegetation type. At this sampling location only fourteen trees were measured. Several isolated trees occurred along the stream channel but these were not included in the sample. Tree diameters averaged 10.5 inches (26.7 cm) and ranged from 6.7 inches

(17.0 cm) to 14.9 inches (37.8 cm). The larger trees were approximately 60 feet tall. The poorly developed tree layer has done little to modify the understory. The areas immediately underneath the trees are covered by fallen needles and very few herbaceous plants grow in this substrate.

The shrub layer is composed of species which also occur in the mixed mountain shrublands and indicate the similarity of these two vegetation types. Gambel's oak and snowberry were the dominant species and occurred at densities of approximately 8200 and 7500 plants per hectare, respectively (Table V-62). The absence of Douglas-fir saplings in the sample suggests that reproductive success for this species is limited in this local area. It is likely that germination and successful establishment of Douglas-fir in these stands occurs only during the most favorable year.

The herb layer in these communities is discontinuous and average herb cover is approximately 25% (Table V-33 and V-34, Stand 21). Common species include fairy candelabra, pussytoes and sheep fescue. Mosses and lichens are common in this community and together they cover nearly 30% of the ground layer (Tables V-33 and V-34).

Stability, Diversity and Succession

Under the existing climatic regime the low elevation Douglas-fir forests appear to be in equilibrium with the environmental parameters. This vegetation type occurs in very restricted sites and sampling data suggest poor reproductive success. It is possible that only a slight climatic change to warmer, drier conditions could cause these communities to shift in the direction of pinyon-juniper woodlands. In the Tract area stands of pinyon-juniper occur which contain few isolated Douglas-fir trees suggesting the close relationship between these two types.

The herb layer diversity-index in the Douglas-fir forests is intermediate to that in other communities and averages 7.5 species per square meter.

Environment

The Douglas-fir forests occur mostly on Rentsac Channery soils on the Tract. The relationship with soil type is probably of secondary importance and the distribution of this vegetation type is probably controlled more by temperature and moisture than by soil type. The steep north-facing slopes on which these communities occur tend to be cooler and more moist than surrounding sites. Even though these conditions are similar to those encountered in mixed shrub communities, Douglas-fir seems to be restricted to those sites where northerly exposure and steepness are greatest.

Fires do occur in the stands of Douglas-fir but are apparently not a factor controlling their distribution. Burned areas occur mostly in the pinyon-juniper woodlands, and where Douglas-fir occurred adjacent to these sites, they also have been destroyed by fire.

Table V-62 SHRUB LAYER SPECIES COMPOSITION FOR DOUGLAS-FIR FOREST
(Stand #21)
(VALUES BASED ON 10, 5 X 20 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Cercocarpus montanus	0.3	10	109	7.4	6
Juniperus scopulorum	0.5	20	430	16.0	4
Pinus edulis	< 0.1	20	215	11.8	5
Quercus gambelii	10.3	50	8176	134.7	1
Ribes cereum	1.8	20	538	24.0	3
Symphoricarpos oreophilus	4.3	70	7531	106.1	2
TOTALS	17.3		16999		

Table V-63 SHRUB LAYER SPECIES COMPOSITION FOR BUNCHGRASS COMMUNITY
(Stand #20)
(VALUES BASED ON 20, 6' X 50' SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	0.4	35	179	31.7	3
Atriplex confertifolia	4.9	85	1686	193.4	1
Atriplex canescens	0.4	20	448	33.8	2
Ceratoides lanata	0.2	10	72	10.7	5
Chrysothamnus nauseosus	0.0	5	18	3.4	7
C. viscidiflorus	0.1	20	161	18.6	4
Opuntia polyacantha	0.0	5	54	4.7	6
Sarcobatus vermiculatus	0.0	5	18	3.4	8
TOTALS	6.0		2636		

Current Land Use and Management

The Douglas-fir forests are grazed by cattle but utilization in these areas is low because of the relative sparseness of the vegetation and also the steepness of the slopes. The number of trees is too low to support any lumbering in the area. These areas have not been managed either for tree production or for increased forage production.

(vi) Mixed Mountain Shrublands

General Location and Distribution

Mixed mountain shrublands represent some of the most widespread and abundant plant communities in the Piceance Creek Basin and are composed of numerous shrub species which are very important for supporting local mule deer populations. Because there are many shrub species which occur as dominants, the structure and composition of this vegetation type varies considerably depending on the slope, exposure, soil conditions and moisture regime. The most typical stands of mixed mountain shrub include serviceberry (Amelanchier alnifolia and Amelanchier utahensis), Gambel's oak (Quercus gambelii), snowberry (Symphoricarpos oreophilus), bitterbrush (Purshia tridentata) and mountain mahogany (Cercocarpus montanus). On some sites big sagebrush (Artemisia tridentata) also plays a dominant role in the vegetation. In addition to these common species numerous other shrubs may occur to a lesser extent. Gooseberry and currant (Ribes spp.), squaw apple (Peraphyllum ramosissimum), mountain lover (Pachystima myrsinites), Oregon grape (Mahonia repens), chokecherry, and skunkbush (Rhus trilobata) are all species in this category. Even though typical stands of mixed shrub include many species, there are sites on which communities dominated by a single species develop. Gambel's oak commonly occurs in early pure stands and is known locally as oakbrush. Mountain mahogany also occurs as an overwhelming dominant species on steep slopes which are relatively dry. In some places serviceberry and big sagebrush occur together as community dominants. The most diverse types of mixed shrublands tend to be located on steep north-facing slopes and usually occur at lower elevations or on more exposed sites than either aspen woodlands or Douglas-fir forests. Shrub-dominated communities, however, are not restricted to those steep slopes, and commonly they occur in some form on ridgetops and southerly-facing slopes at higher elevations. There seems to be a very well-pronounced relationship between the compositional character of the mixed shrub community and the topographic feature on which it develops. The mixed mountain shrub communities on the Tract study area are limited in distribution and occur mostly on northerly-facing slopes.

Structure and Composition

The mixed shrub communities are composed of numerous shrub species (Gambel's oak, serviceberry, mountain mahogany, chokecherry, juneberry, snowberry and Oregon grape) which comprise typical stands of mixed mountain shrublands. The communities show stratification even among shrub species. The vegetation canopy is composed primarily of larger

shrub species (Gambel's oak, serviceberry and mountain mahogany). However, in some places snowberry forms a nearly continuous layer in the understory.

Herb-species composition is varied and includes numerous species characteristic of more mesic vegetation types (Watson's beardtongue, fairy candelabra, pasque flower, sugar bowls and elk sedge). Low growing shrub species like mountain lover and Oregon grape are also common in the herb layer.

In addition to the larger stands of mixed shrublands small pockets of this vegetation type occur in the numerous gulches which are common on Tract. These areas are varied in composition. In many locations small groves of Gambel's oak occur at the upper ends of the lateral gulches which feed into the major drainages of the Tract. At other sites patches of chokecherry occur in these gulches. Many species characteristic of the mixed shrublands occur along the intermittent stream channels forming miniature isolated patches of mixed shrublands. Even though these areas are small, they provide important habitats for wildlife species.

A somewhat different form of mixed shrubland occurs on the ridge immediately west of Little Scandard Gulch (Figure V-44). In this community sagebrush, serviceberry and bitterbrush occur as dominant species. This form of mixed shrubland is more common at higher elevations, especially on the ridgetops. In many ways it represents a transitional type between upland sagebrush and typical mixed-mountain shrub.

Stability, Diversity and Succession

The mixed shrub communities in their typical form represent stable communities unlikely to change as a result of succession. The large number of shrub species which characterize this vegetation type provide an element of stability lacking in low diversity shrub communities. The relationship between diversity and stability has received considerable attention in recent ecological publications and both supporting and refuting articles can be found. In the case of the mixed shrublands on the Tract the diversity of shrub species could be very important, especially if one of the dominant species was found to be intolerant of industrial development. Where diversity is higher, a greater resiliency potentially exists.

Environment

The environmental characteristics in the mixed shrub communities provide some of the most favorable conditions for plant growth within the study area. The soils are mostly of the Redcreek-Rentsac type but these appear to have been locally modified by the vegetation and are therefore considerably different than these same soil types developed in pinyon-juniper woodlands. Snow has a tendency to collect on these sites and slow melting in the spring allows good percolation. Because of the north-facing slope aspect, soil moisture remains at high levels

throughout the growing season (Table V-37). Better moisture conditions promote increased production which eventually results in higher soil organic matter content.

Fire does not seem to be an important factor in these communities. Some evidence of fire has been noted but it does not appear to play an important role in determining the distribution of the mixed shrublands.

Current Land Use and Management

The mixed shrublands are currently used as livestock grazing areas during the summer months. No management practices have been employed in these communities.

(vii) Bunchgrass Community

General Location and Distribution

The bunchgrass communities occur primarily on steep talus deposits on the sides of the major valleys. Topographically they occupy intermediate positions between pinyon-juniper woodlands (located above the talus slopes). Bunchgrass communities also occur on the burned pinyon-juniper sites on the Tract. These sites tend to be relatively level; however, other environmental conditions make them similar to the talus slopes (e.g., solar radiation, soil moisture). The best-developed bunchgrass communities on steep slopes occur near the existing main entrance to the Tract (P-L Ranch) along Piceance Creek. In West Fork Stewart Gulch these communities occur as narrow bands between the bottomland sagebrush and pinyon-juniper woodlands.

Structure and Composition

The shrub layer in the bunchgrass communities is poorly developed and total density is approximately 2600 shrubs per hectare (Table V-63). Along Piceance Creek (Stand 20) the predominant shrub species are shadscale (Atriplex confertifolia) and four-winged saltbush (Atriplex canescens). It is interesting that saltbush occurs on these sites and its presence suggests above-normal salt concentrations in the soil. High salt concentrations characterize the alluvial fan deposits which occur immediately below Stand 20. It is possible that the determining factors causing the saline conditions in those communities may also be influencing the talus deposits. The specifics of these factors are not yet determined.

Herb layer cover in the bunchgrass communities averages approximately 30%. The dominant herb species in these communities is Indian ricegrass (Oryzopsis hymenoides) with a 90% frequency. This species is widespread throughout the Tract area but it reaches its maximum development in these communities. Other common herb layer species include wild buckwheat (Eriogonum lonchophyllum), cheatgrass, and brickelbrush (Brickellia grandiflora). In the ground layer 55% of the area is covered by bare soil and rock; accumulated plant litter provides only 35% cover (Table V-33).

Stability, Diversity and Succession

The bunchgrass communities which occur on the talus slopes represent ecologically stable communities which are unlikely to be replaced by any other vegetation type. The species which grow on these sites are adapted to the extreme environmental characteristics and unstable soil conditions. Species diversity in these communities is low and averaged only 5.5 species per square meter.

The bunchgrass communities developed in burned-over areas are successional and will eventually be replaced by pinyon-juniper woodlands or upland sagebrush communites.

Environment

The steep talus slopes where the bunchgrass communities occur present some of the most severe environmental conditions in the area. Many of these communities have south-facing exposures which tend to be warm in the winter and hot in the summer. The sparse bunchgrass cover allows penetration of solar radiation to the soil surface during the day and also allows substantial re-radiation of long-wave radiation during the night, thereby causing considerable daily temperature fluctuations. The coarse soils have poor water retaining properties which, along with high growing season temperatures, tends to increase evaporative losses. These communities occur mostly on Rentsac channery and Rentsac-Redcreek soils (Figures V-44 and Chapter VII). These are mostly light-to-medium-textured soils with sufficient nutrient levels except for phosphorus and potassium which may be present in low or deficient amounts.

The bunchgrass communities are mostly snow-free in winter since the south-facing slopes melt free of snow in a few days. Fire does not play a significant role in the bunchgrass communities which occur on the talus slopes. However Indian ricegrass does respond favorably to burning and on some sites in burned pinyon-juniper woodlands it assumes dominance under post-fire conditions.

Current Land Use and Management

The bunchgrass communities are currently used for livestock grazing. Utilization is mostly restricted to late fall or early winter periods. Sparseness of the vegetation, limited areal extent and the steepness of the slopes make these areas less important to livestock than the areas containing more widespread native vegetation types. These communities are not being managed for forage production.

(viii) Marshlands

General Locations and Distribution

In this semiarid region of western Colorado aquatic environments are very limited in extent, especially at elevations below 7000 feet. The most commonly encountered water bodies in the area are small reservoirs

created either for stock-watering or irrigation purposes. In places where the water supply is constant and standing water is shallow, marshes have developed. These communities are regionally uncommon and occur only on floodplains of major drainages. Within the Tract study area several small marshes occur. However, none occur within the Tract boundary. Two large marshes (10 and 13 acres) occur along Piceance Creek approximately 2 and 4 miles upstream from the main entrance to the Tract. A third, smaller marsh (5 acres) occurs along Willow Creek, approximately 2-1/4 miles upstream from its point of confluence with Piceance Creek.

Structure and Composition

The vegetation in the marshes is composed primarily of perennial herbaceous aquatic and semi-aquatic plants. A few willows occur but these are small and inconspicuous. The dominant species include cattail (*Typha latifolia*), common reed (*Phragmites austrasis*) and numerous species of sedges (*Carex* spp.) and rushes (*Juncus* spp.).

Stability, Diversity and Succession

The dominant species which occur in the marshes are adapted to the saturated soil conditions characteristic of these areas. As long as the environmental conditions remain wet, the marshes will continue to persist with few noticeable changes in vegetation structure. If, however, the sites were to dry out, the marshes would be replaced by a more mesic vegetation type such as a sedge meadow. The dominant aquatic species characteristically become rapidly established in uncolonized wet areas. Cattails, especially, have small, light,wind-blown seeds which are produced in abundance. Because of the rapidity with which these communities become established and well-developed, it is difficult to determine how long the marshes have dominated the sites within the study area. It is possible that these marshes have developed since settlement times as a result of ponding of overland-flow irrigation waters. If the sites have always been water collection areas, then the marshes are much older.

Environment

Because of the standing water, the environmental conditions in the marshes are considerably different from those in surrounding areas. Soils are continually saturated, and,because of the great amount of unutilized production, soil organic matter concentrations are high. Other factors, such as precipitation, atmospheric moisture and wind, which are important factors in surrounding communities, are relatively unimportant in the marshes.

Current Land Use and Management

The marshes along Piceance Creek occur in non-fenced areas adjacent to agricultural meadows and pastures. Consequently, these areas are highly utilized by cattle during the winter months when livestock are kept in these lower valley meadows. Much of the marsh vegetation is consumed annually or trampled by the grazing livestock.

(ix) Riparian Communities

General Location and Distribution

The riparian communities are located along the sides of the major streams in the area. Within the study area the best developed riparian areas are along Piceance Creek, Willow Creek and the lower portions of Stewart Creek. Within the Tract boundary there are no riparian areas.

Structure and Composition

The vegetation along the streams is composed of sedges, rushes, horsetails (Equisetum spp.) and species of grasses (Agrostic alba, Phleum pratense, Beckmannia syzigachne). Other streamside species include marsh elder (Iva xanthifolia), checker mallow (Sidalcea neomexicana), nettle (Urtica dioica) Nuttall's sunflower (Helianthus nuttallii) and Canada goldenrod (Solidago canadensis). Willows (Salix spp.) occur to a limited extent; most of the individuals are small and isolated. The riparian vegetation is mostly restricted to stream trenches except in those areas where the banks slope gently to the stream bed. The riparian communities along Piceance Creek are bordered by large meadows. The separation of the meadows and riparian communities are indistinct and many semiaquatic species occur in the moist agricultural meadows. In other streamside areas the riparian communities exist as narrow bands immediately adjacent to the streams.

Stability, Diversity and Succession

The riparian vegetation constitutes a stable community maintained by relatively constant stream flow. The species composition in these communities is relatively constant; variation from site to site is low. In many places the streamside vegetation has been altered because of irrigation practices. Recovery from disturbance is rapid, primarily because of the favorable moisture conditions associated with these communities. Construction of irrigation ditches has done much to increase the extent of this vegetation type since the environmental conditions along the ditches are much the same as those along the streams.

Environment

The environmental conditions along the stream are very favorable for plant growth. Moisture is present in abundant amounts and in some cases saturated soil conditions may limit species diversity by allowing only aquatic species to grow. Soil nutrients are plentiful, and irrigation return flows enrich the naturally high nutrient levels.

Current Land Use and Management

The streamside communities are grazed by livestock, with utilization concentrated mostly in the winter months. Most of the grasses, forbs and some of the smaller willows are annually consumed by the cattle. The livestock also affect the vegetation by trampling, which can be substantial, especially in the soft, wet soils.

(x) Great Basin Wild Rye Communities

General Location and Distribution

After the arrival of the first ranchers in the Piceance Creek basin region, reports of grasses taller than a horse and rider filtered back into the early settlements. This grass was Great Basin wild rye (Elymus cinereus) which prior to settlement had occurred in dense stands on the floodplains of larger streams. Many of the areas formerly dominated by Great Basin wild rye have been converted into agricultural meadows and pastures, and only a few areas of this vegetation type remain. The valley floors of the major streams consist of three different land forms: alluvial fans, floodplains and stream channels or trenches. These land forms each support different vegetation types. However, these types intergrade and overlap slightly.

Depending on soil salt concentration, the alluvial fans support either big sagebrush (intermediate salt levels) or greasewood (higher salt concentrations). The stream trenches support narrow bands of lush semi-aquatic vegetation, and the flat floodplains originally supported Great Basin wild rye communities. Remnants of this original pattern of vegetation along areas like Piceance Creek can still be found along the upper reaches of the stream about four miles west of the Rio Blanco store.

On the Tract study area stands of Great Basin wild rye are restricted to small floodplain areas along Willow Creek and East Fork Stewart Gulch. These locations likely have never been plowed or improved for irrigation, and for these reasons the wild rye has persisted.

Structure and Composition

The dominant species in these communities is Great Basin wild rye, which occurs as tall, robust clumps. This species is non-rhizomatous and consequently it does not produce a continuous cover. However, where the large clumps occur, the cover is dense. Other common species include cheatgrass and mountain peppergrass. Few shrubs occur in these communities, but big sagebrush plants are occasionally encountered.

Stability, Diversity and Succession

If undisturbed, the Great Basin wild rye communities show considerable stability. Mention of their occurrence by early settlers and land surveyors indicates their presence as a community type in the late 1800's. The individual grass clumps appear to be long-lived, and reproduction and seedling establishment attest to the continued success of the dominant species. The original extent of these communities has been considerably reduced because of their location on arable floodplain sites. No successional changes have been noted in these communities, and they appear to be the ultimate plant community which naturally develops on the floodplain sites.

Environment

The Great Basin wild rye communities occur on medium textured alluvial soils, primarily of the Glendive loam type. These soils are saline due

to excessive amounts of sulfate and sodium. Great Basin wild rye is apparently adapted to these salty conditions and is not eliminated from saline sites until salt levels are considerably higher. The Glendive soils have high levels of nitrogen, phosphorus and potassium, and of measured nutrients only zinc is deficient.

Current Land Use and Management

The Great Basin wild rye communities are used as grazing areas mostly in the winter. The tall grasses are rather coarse and unpalatable but they are utilized to some extent by cattle.

(xi) Rabbitbrush Communities

General Location and Distribution

In the Piceance Creek Basin two species of rabbitbrush are commonly encountered (Chrysothamnus nauseous and Chrysothamnus viscidiflorus). The latter is more common at higher elevations where it occurs as a subdominant species in upland sagebrush communities and mixed mountain shrublands. It very rarely attains large size or community dominance and does not occur in pure stands. Rubber rabbitbrush (C. nauseous) is a much more common species at lower elevations and rarely occurs in abundance in upland plant communities. It is frequently encountered in chained rangelands, but in these areas it does not assume community dominance. On floodplains and valley floors this species occurs at high densities and forms communities in which few other shrub species occur. The distribution of this vegetation type in the Tract area is restricted to floodplain areas which have apparently been disturbed in some manner since settlement times. The best development of rabbitbrush occurs at the mouth of West Fork Stewart Gulch. Other small stands of this community type occur elsewhere in the Stewart Creek drainage and also in the upper portions of Willow Creek valley.

Structure and Composition

The shrub layer of the communities is dominated by rubber rabbitbrush which has an average cover of 43% and occurs at approximate densities of 11,000 shrubs per hectare (approximately equal to one shrub per square meter). The only other shrub species which occurs in those communities is big sagebrush (Table V-64).

The herb layer is composed primarily of mountain peppergrass (100% frequency), western wheatgrass (95% frequency) and cheatgrass (95% frequency). In addition to these three species numerous other weedy species occur (Tables V-33 and V-39, Stand 17). The herb layer species composition in these communities is very similar to that encountered in the valley sagebrush communities and suggests a relationship between these two types. Additionally, the presence of introduced annual weed species indicates grazing disturbances.

Table V-64 SHRUB LAYER SPECIES COMPOSITION FOR RABBITBRUSH COMMUNITY
(Stand #17)
(VALUES BASED ON 20, 6 X 50 SHRUB TRANSECTS.)

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	0.3	31.58	452	28.6	2
Chrysothamnus nauseosus	43.2	100.00	10910	271.4	1
TOTALS	43.5		11362		

Table V-65 SHRUB LAYER SPECIES COMPOSITION FOR GREASEWOOD COMMUNITY
(Stand #18)
(VALUES BASED ON 20, 6' X 50' SHRUB TRANSECTS

SPECIES	COVER %	FREQUENCY %	#/HECTARE	IMPORTANCE VALUE	RANK
Artemisia tridentata	.1	10	356.	7.2	3
Atriplex canescens	0.3	5	18.	4.5	4
Chrysothamnus nauseosus	3.2	40	699.	46.9	2
Sarcobatus vermiculatus	27.1	100	5918.	242.7	1
TOTALS	30.7		6671		

Stability, Diversity and Succession

Based on observations of vegetation patterns in bottomlands within the study area, it appears that rabbitbrush communities constitute a successional vegetation type rather than a stable community. In some areas boundaries of rabbitbrush communities are defined by livestock fences, suggesting the development of this type in response to agricultural activities. The rabbitbrush appears to be developed on sites which were previously covered by valley sagebrush communities.

Successional changes may be expected in the rabbitbrush communities if current grazing practices are continued. It is possible, however, that the disturbances which allowed the development of the rabbitbrush caused significant enough changes that valley sagebrush communities may not recover on these sites even if grazing were to be discontinued.

Environment

Environmental conditions in the rabbitbrush communities are very similar to those in the valley sagebrush sites. Both of these communities occur on Glendive soils which contain excessive amounts of sodium and sulfate. Soil moisture averaged about 25% during the growing season (June-August) which is a surprisingly low value for a valley site. However, it is consistent with other valley soil moisture values. Soil nutrients are present in normal or above-normal amounts, and zinc is the only nutrient which exhibits a deficiency.

Fire may play a role in the establishment of rabbitbrush communities. Sagebrush is intollerant of fire, and it may be possible that rabbitbrush recovers more quickly on burned sites.

Current Land Use and Management

The rabbitbrush communities are used for livestock grazing, but they are not managed for range improvement.

(xii) Greasewood Communities

General Location and Distribution

Throughout western Colorado, greasewood communities characteristically occur on alluvial deposits which usually contain high concentrations of soil salts. Extensive areas of greasewood and saltbush occur in the cold salt-desert regions of northwestern Colorado. The overall range of this community extends into the Piceance Creek Basin region, but here, it is restricted to valley bottoms and alluvial fans where local salt levels are high. In the Tract study area greasewood communities are restricted to alluvial fans along Piceance Creek. Isolated individuals occur elsewhere on the Tract, but greasewood community development is restricted to these sites.

Structure and Composition

The species composition in the greasewood communities strongly reflects the intensive grazing utilization which they receive. The greasewood stands are located on the fenced portions of the Piceance Creek floodplain where livestock are wintered. Heavy grazing and trampling cause continued disturbances which provide favorable conditions for the growth of weedy species.

The dominant species in these communities is greasewood (Sarcobatus vermiculatus) which provides an average cover of 27% and occurs at a density of approximately 5900 individuals per hectare (Table V-65). The shrub layer is relatively open and the individual shrubs tend to grow in clumps rather than form a continuous canopy. Rabbitbrush (Chrysothamnus nauseousus) occurs as a secondary dominant species, but it is far less abundant than is greasewood.

The herb layer is composed of relatively few species which most likely resulted from disturbance and high soil salt-concentrations. The most common herb species are crested wheatgrass (Agropyron cristatum) and cheatgrass, both of which are introduced species. The crested wheatgrass was probably seeded into this area in order to provide more forage for cattle. Total herb cover was about 43% and was mostly provided by the two dominant species.

Stability, Diversity and Succession

The greasewood communities constitute an ecologically stable,vegetation type in the Tract study area. The environmental conditions under which these communities grow are such that few other species can successfully compete with the community dominants. Even though herb diversity is very low (3 to 4 species per square meter), these communities demonstrate considerable resiliency and tolerance of continued heavy utilization and disturbance. The stands of greasewood which occur within the area most likely have been growing on these sites since pre-settlement days. Individual plants have matured and died during this time interval, but the basic appearance of these communities has not been altered.

Environment

The greasewood communities occur on Hanly loam soils which are medium-textured, basic and characterized by excessive amounts of nitrates, sulfates and sodium. Excessive levels of these nutrients are deleterious to plant growth and only certain species are adapted for growth under these conditions. The high salt levels appear to be caused by runoff and its associated sediment load and associated salts. These materials are deposited on the fans. Rate of runoff and low soil permeability prohibit deep soil wetting and leaching of salts into deeper soil strata. Salts concentrate in the upper soil levels as the moisture evaporates from the surface. In addition, remaining salts, deposited earlier in the development of the alluvial fan, are carried upward to the surface by capillary action. Greasewood plants are phreatophytic, which means they tap the water supply at the capillary fringe of the ground water table. By being tolerant of the salty conditions, these plants are assured of a continuous water supply throughout the growing season. Surface salt concentrations may also be increased by leaching of the litter (dead leaves and twigs) which fall from the greasewood plants.

Other environmental factors appear to be less important in the growth of the communities. Soil moisture is important for the herbaceous species and tends to be sufficient early in the growing season.

The species in the greasewood communities are intolerant of fire so that when fires occasionally occur they cause considerable damage. No evidence of fire in the greasewood communities has been noted within the Tract areas.

Current Land Use and Management

The greasewood communities are used as grazing areas during the winter months. In addition to providing limited forage the tall shrubs also provide some protection from winter winds. The presence of crested wheatgrass in these communities suggests some range-improvement seeding, however these communities are not managed for range improvement.

(xiii) Agricultural Meadows

The agricultural meadows in the Tract area are restricted to floodplain areas along the major streams. These communities are composed primarily of alfalfa and introduced pasture grasses. The areas are used for hay production during the summer months when cattle are kept on native summer rangelands. During winter months the agricultural meadows are used as grazing areas.

The primary non-industrial occupation within the Tract area is cattle ranching. The agricultural meadows form an important link in total nutrient cycling and energy flow in the livestock-vegetation system (Figure V-50). Irrigation waters from Piceance Creek are used to increase hay production in the floodplain meadows. Usually only a single cutting of hay is produced and stacked for winter feeding to cattle. Regrowth of hay species is left standing in the fields and is utilized by livestock when they are returned to the lower valleys for the winter. Limited areas of native vegetation (marshes, riparian communities, greasewood and sagebrush communities) which occur on the floodplain pasture areas are also utilized by cattle during the winter months. Little, if any, of the hay crop is exported from the system. Most of the year's production is used to sustain cattle herds through the winter months. Nutrients and unassimilated materials are therefore retained in the system in the form of cow dung. The final products of the system are marketed cattle. Individuals lost to natural causes return to the system via decomposition. Energy losses in the form of heat or respiration characterize all energy conversion reactions.

During the summer cattle graze on native vegetation at higher elevations where energy flow and nutrient cycling follow patterns characteristic of natural systems. The cattle are dependent on native grass and forb production and recycle nutrients through elimination of non-utilized materials and through death and decomposition.

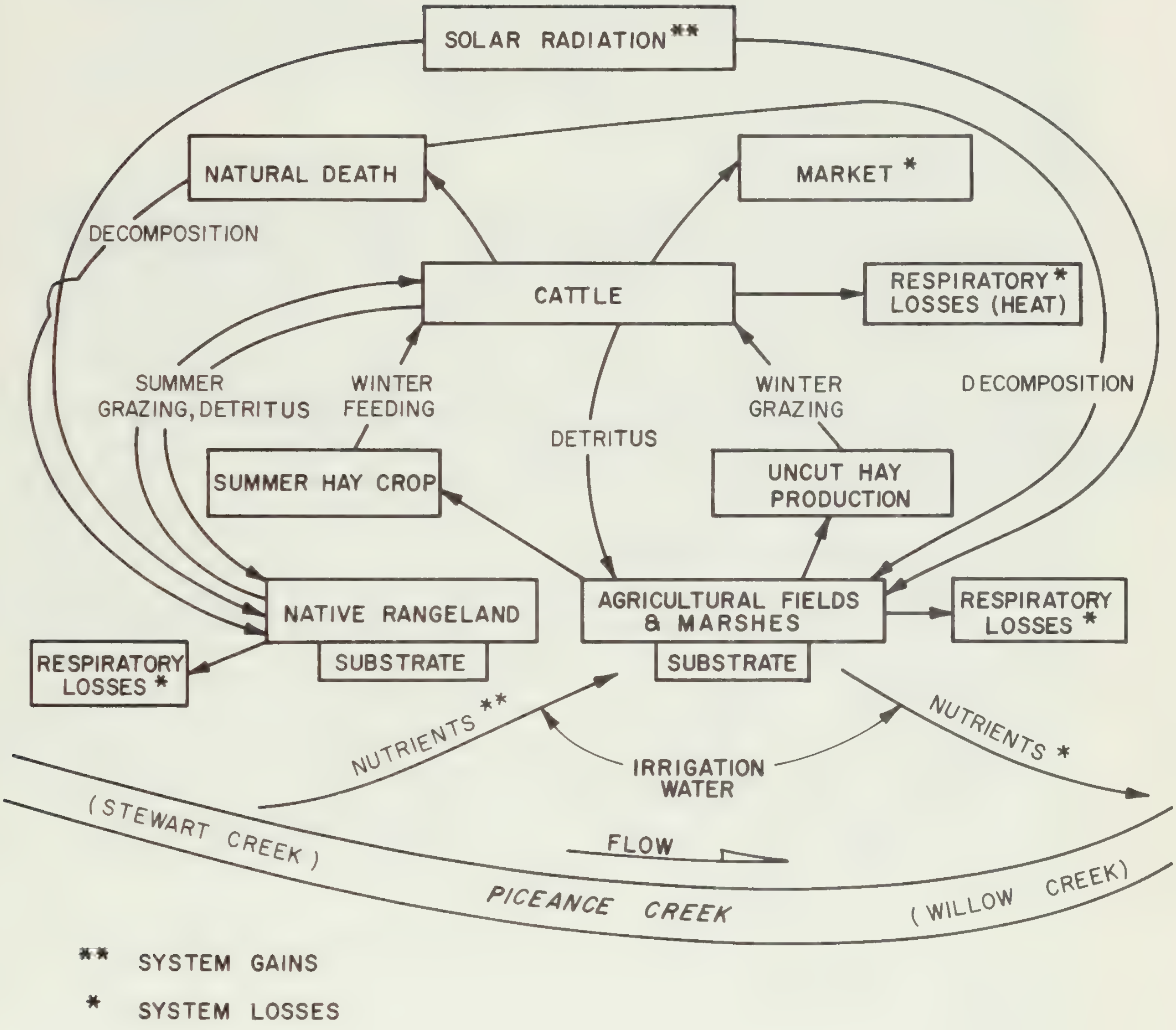


Figure V-50 FLOW OF ENERGY THROUGH LIVESTOCK-VEGETATION SYSTEM

(xiv) Annual Weed Communities

General Location and Distribution

The annual weed communities comprise a somewhat artificial vegetation type which develops on disturbed sites. Disturbances stem from recent industrial development activities (well drilling platforms and access roads) and ranching activities (stock holding and ranchyard areas). Location of these areas follows no pattern, and as might be expected, the appearance of the vegetation which develops on disturbed sites varies considerably from site to site.

Structure and Composition

The vegetation on the disturbed sites is composed primarily of annual weeds. On some sites perennial grasses have become established, but they currently occur in limited amounts. Shrubs are generally lacking from any of the disturbed sites; however, an occasional individual may be encountered. Dominant species on these sites include annuals such as cheatgrass, white pigweed (*Amaranthus albidus*), tumble mustard, Russian thistle (*Salsola kali*) and goosefoot (*Chenopodium album*). Western wheatgrass and Indian ricegrass are the most commonly encountered perennial grasses. A total of 39 species was encountered in sampling the disturbed sites (Tables V-33 and V-34, Stands 22-28).

Stability, Diversity and Succession

The annual weed communities represent the first successional vegetation stages which develop on disturbed sites. In this regard the communities are ecologically unstable and are changing in the direction of equilibrium vegetation types. The final vegetation type which will eventually occupy these sites is primarily determined by the surrounding vegetation. Disturbed sites in the valleys will most likely support sagebrush communites while upland sites will probably develop as pinyon-juniper woodlands. The transition back to stable communities will require a long period of time. Re-establishment of pinyon-juniper woodlands may take as long as 200 years. Because of reduced complexity, shrublands may require only 60 to 70 years to reach stable conditions.

Diversity on the disturbed sites was low and averaged only 4.2 species per square meter in the sampled stands.

Environment

Environmental conditions in the annual weed communities are harsh and not conducive to plant growth. Soil characteristics have been altered by disturbance and on some sites coarse subsurface materials have been brought to the surface. Soil surface temperatures fluctuate daily over wide extremes owing primarily to a poorly developed vegetation canopy and lack of plant litter. Soil organic matter content is low but will increase as the successional sequence progresses.

Current Land Use and Management

Cattle utilize these areas incidentally as they graze throughout the native vegetation communities.

Management has been limited to reclamation and revegetation of some of the sites.

5. Aquatic Plant Communities

a. Lentic

Ponds and lakes are forms of lentic communities. In the ponds near the Tract organic content is high and the bottoms of the ponds are covered with a fine sedimentary ooze. Pondweeds (Potomogaton spp.) are found in most of the ponds. Because the ponds are maintained by ranchers, they have not gone through the succesional stages as quickly as might be expected.

b. Lotic

Rivers, streams, seeps and springs are all forms of lotic communities. Piceance Creek supports local concentrations of watercress (Rorippa nasturtium aquaticum) which is one of the commonly encountered species in the stream. Piceance Creek is greatly affected by irrigation diversion. However, in the spring snow runoff swells the stream and increases the silt loading. Cold water temperatures and the high turbidity tend to retard the growth of plant and algae. By late summer, however, warmer water temperatures encourage the growth of the aquatic plants which grow in the stream.

6. Soil-Vegetation Interrelationships

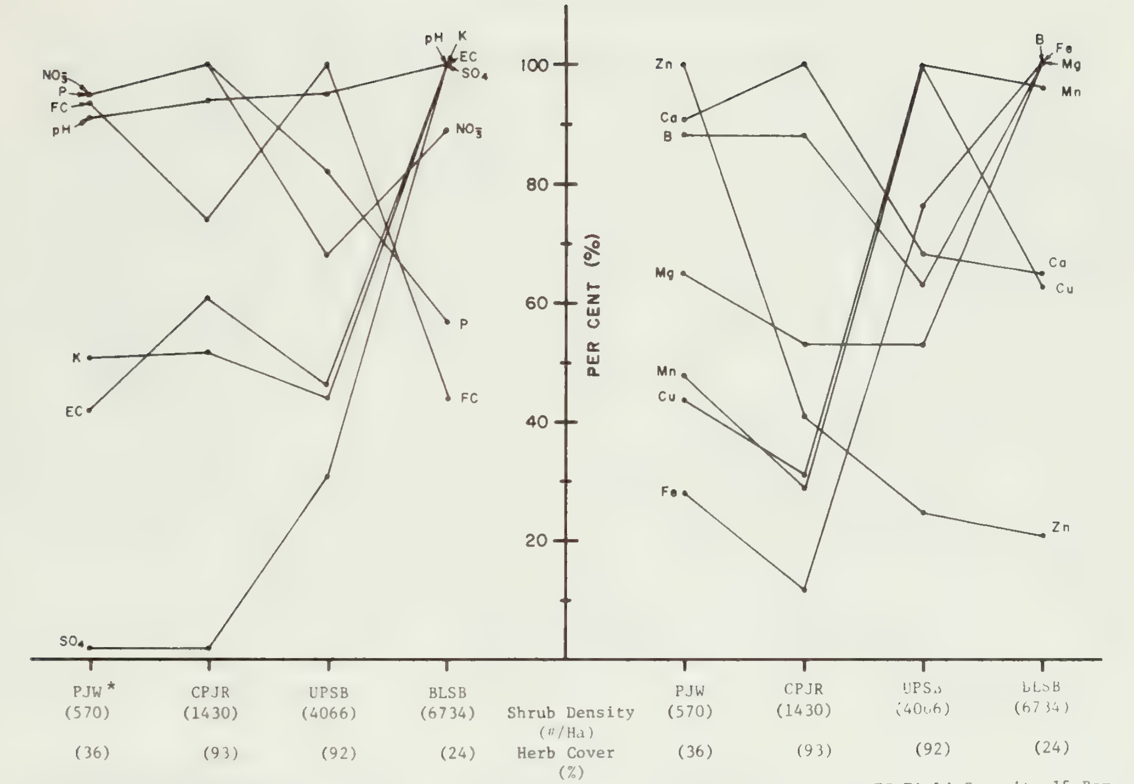
Preliminary correlations of soil characteristics with the four major plant communities occurring on Tract C-b have been completed. These analyses are summarized in Figure V-51, which shows the relative values* for nitrate-nitrogen, phosphorus, potassium, boron, calcium, copper, iron, magnesium, manganese, salts (electrical conductivity), sulphate-sulphur, zinc, pH, field capactiy (15 Bar) and percent soil moisture in relation to each of the four major plant communities in terms of shrub density per hectare and percent cover by herbaceous species.

The analysis of these data do not reveal the presence of strong trends between vegetation type and soil characteristics. A number of important features are indicated however: 1) none of the vegetation types have high nutrient regimes; 2) all are deficient in zinc with a general trend toward decreasing zinc in sagebrush-dominated stands particularily the bottomland sites; 3) most stands are low in phosphorus and potassium, excepting the high potassium values in bottomland sagebrush sites; 4) iron tends to increase in sagebrush-dominated sites; 5) pH is uniformly high; 6) total salts (EC) and sulphate increase in sagebrush-dominated sites. These general characteristics and trends point to the marked differences between woodland and range sites as a group and big sagebrush communities as another group. The high densities of sagebrush indicate a tolerance by sagebrush for high salts, low available soil water and high pH.

Other indications (cf. Soil Productivity Assessment, Quarterly Data Report #3, Section II D-5) show that chained rangelands are the most productive sites, this having been attributed to more substantial populations of soil microorganisms in this vegetation type. An important factor in the availability of phosphorus is a neutral pH (near 7.0) which also exerts a strong influence on the activity of microorganisms (Brady,1974).

Correlations of soil chemical characteristics with individual shrub and herbaceous species compositional data have also been completed. Gradients of nutrient and other soil characteristics have been constructed in Figures V-52 through V-79. These gradients are based on samples collected in five stand types (pinyon-juniper woodland, pinyon-juniper, chained rangeland, upland sagebrush, bottomland sagebrush and greasewood). The values represented in these gradients are from analysis of the top six to ten inches of soil in these sites. Nutrient values were arranged on a relative gradient indicating a range of values which were fitted into categories from deficient to excessive. Not all categories were applied to each element, but instead the applications correspond to the actual range indicated in the data. Within this range of categories

* Values shown in Figure V-51 have been computed from actual nutrient values by using a ratio. The highest value for a given nutrient in one of the 5 stands was set equal to 100%, all other values were then adjusted proportionately.



* PJW-Pinyon-Juniper Woodlands
CPJR-Chained Pinyon-Juniper Rangelands
UPSB-Upland Sagebrush
BLSB-Bottomland Sagebrush

N-Nitrate
P-Phosphorus
K-Potassium
Ca-Calcium
Mg-Magnesium

Mn-Manganese
Zn-Zinc
Cu-Copper
B-Boron
Fe-Iron

FC-Field Capacity 15 Bar
EC-Electrical Conductivity
SO_4-Sulfate

Figure V-51
SOIL NUTRIENT SUMMARY FOR THE FOUR MAJOR VEGETATION TYPES IN THE TRACT C-b STUDY AREA

for which soil element values were averaged, species values for seven shrub species (Figure V-52) and frequency of ten herbaceous species (Figure V-53) were also averaged.

Interpretation of the soil-vegetation gradients is complex. Although the existence of species relationships to nutrient gradients is frequently indicated, these should not be confused with the probable interaction between species which is of equal importance on species behavior in many instances. The following interpretations of soil-vegetation relationships are presented.

a. Nitrate-Nitrogen (Figures V-52 and 53)

Shrubs. The relationship between seven shrub species and nitrate is based on three categories of nitrate: a normal level (7 ppm), a high level (28 ppm) and an excessive level (51 ppm). Big sagebrush (Artemisia tridentata) and serviceberry (Amelanchier spp.) show general declines in stand importance as nitrate increases. This implied relationship between the importance of sagebrush and nitrate is supported by the lower nitrate levels in bottomland sagebrush stands and upland sagebrush stands (Figure V-51). Antelope bitterbrush (Purshia tridentata) on the other hand demonstrates a general increase in importance with increasing nitrate, particularily at excessive levels. This relationship implies a tolerance of bitterbrush for excessive nitrate, the counteracting effects of high calcium in these stands, or a combination of these effects with decreased competition with big sagebrush. The general increase of rubber rabbitbrush (Chrysothamnus nauseosus) indicates a tolerance for nitrate excesses and also implies the effects of decreased competition with sagebrush. Other species domonstrate little in terms of trends, beyond a noted intolerance for excessive nitrate. The sharp rise of snowberry (Symphoricarpos oreophilus) at high levels may be a response to reduced competition with sagebrush; the sudden decline is ostensibly related to an intolerance for excessive nitrate, but may also be related to excessive salts and sulphate (Figures V-70 and 72).

Herbs. There is a noted intolerance of the majority of herbaceous species studied for excessive nitrate. Western wheatgrass (Agropyron smithii) is a noteable exception. The response of western wheatgrass to increasing nitrate across the gradient is an explanation of its predominance in the herb layer in the majority of stands sampled.

b. Phosphorus (Figures V-54 and 55)

Shrubs. The inverse correspondence between big sagebrush and other shrub species is apparent in this gradient. The decrease in the importance value of big sagebrush at normal levels of phosphorus is matched by an increase in several other shrub species, noteably antelope bitterbrush and pinyon pine (Pinus edulis) saplings. These responses are ostensibly because of the competitive interactions between big sagebrush and the other two species; the nature of the competition is possibly attributable to high nitrate values in these stands. The

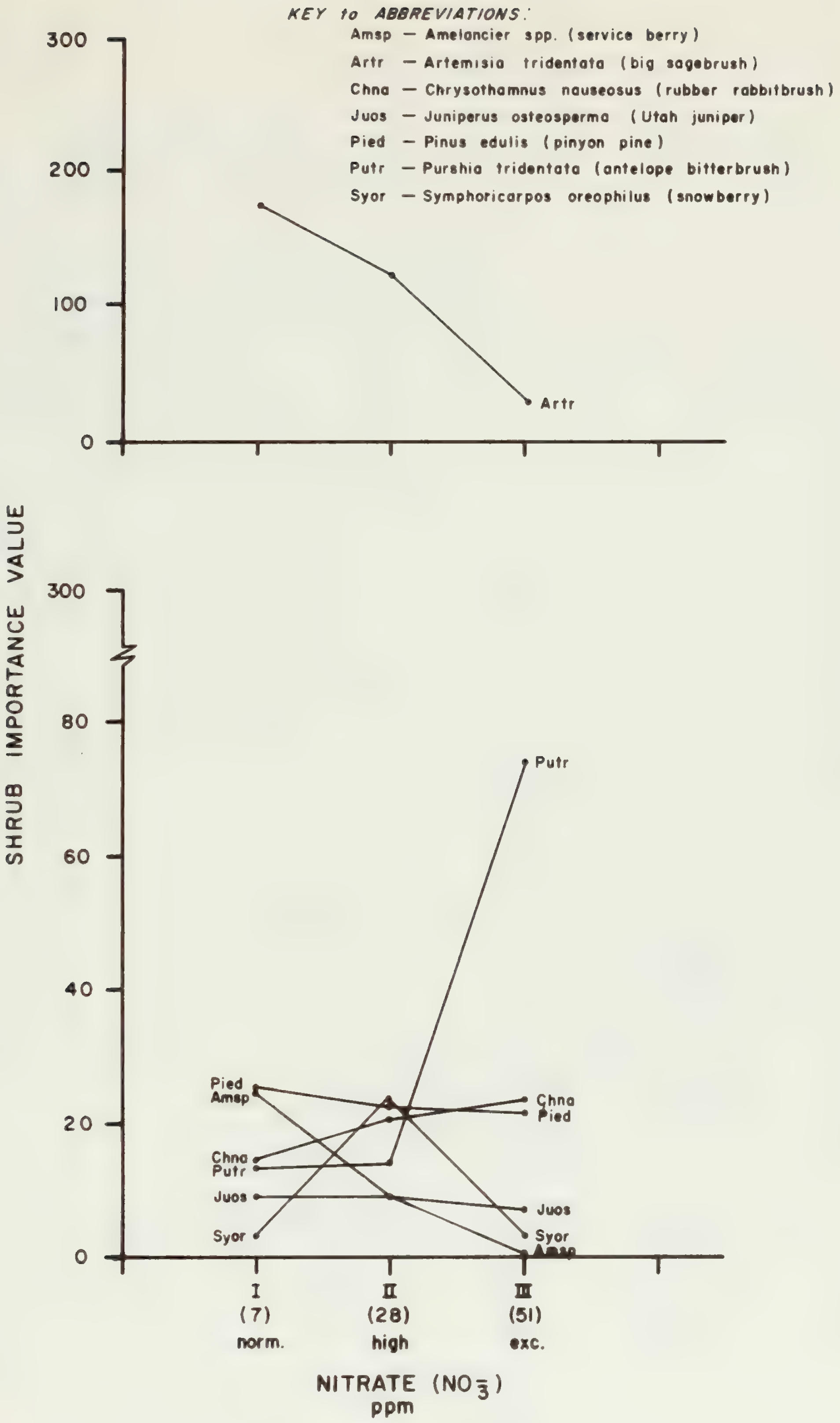


Figure V-52
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A NITRATE-NITROGEN GRADIENT IN THE SOIL SURFACE LAYER.

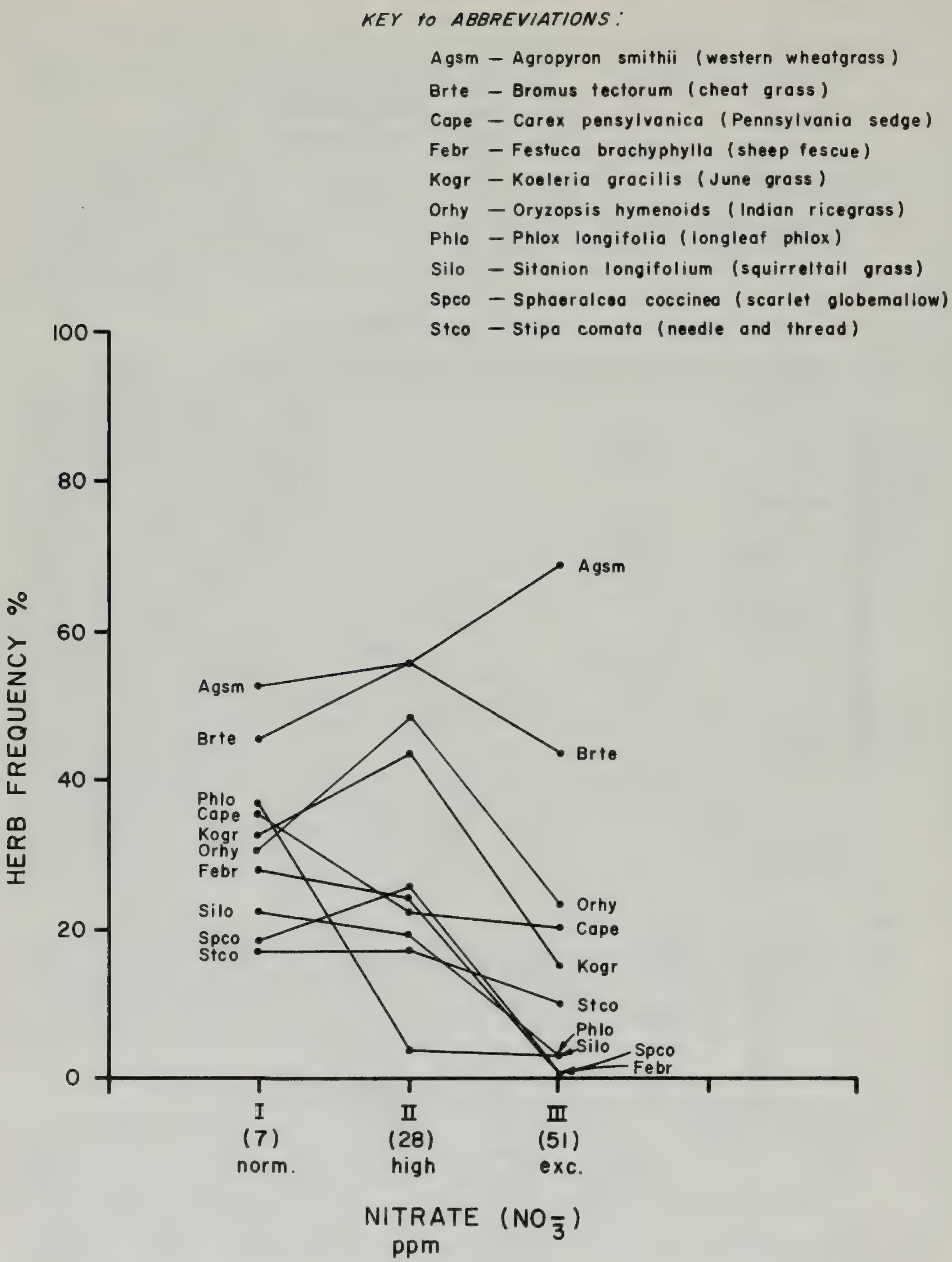


Figure V-53

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A NITRATE-NITROGEN GRADIENT IN THE SOIL SURFACE LAYER.

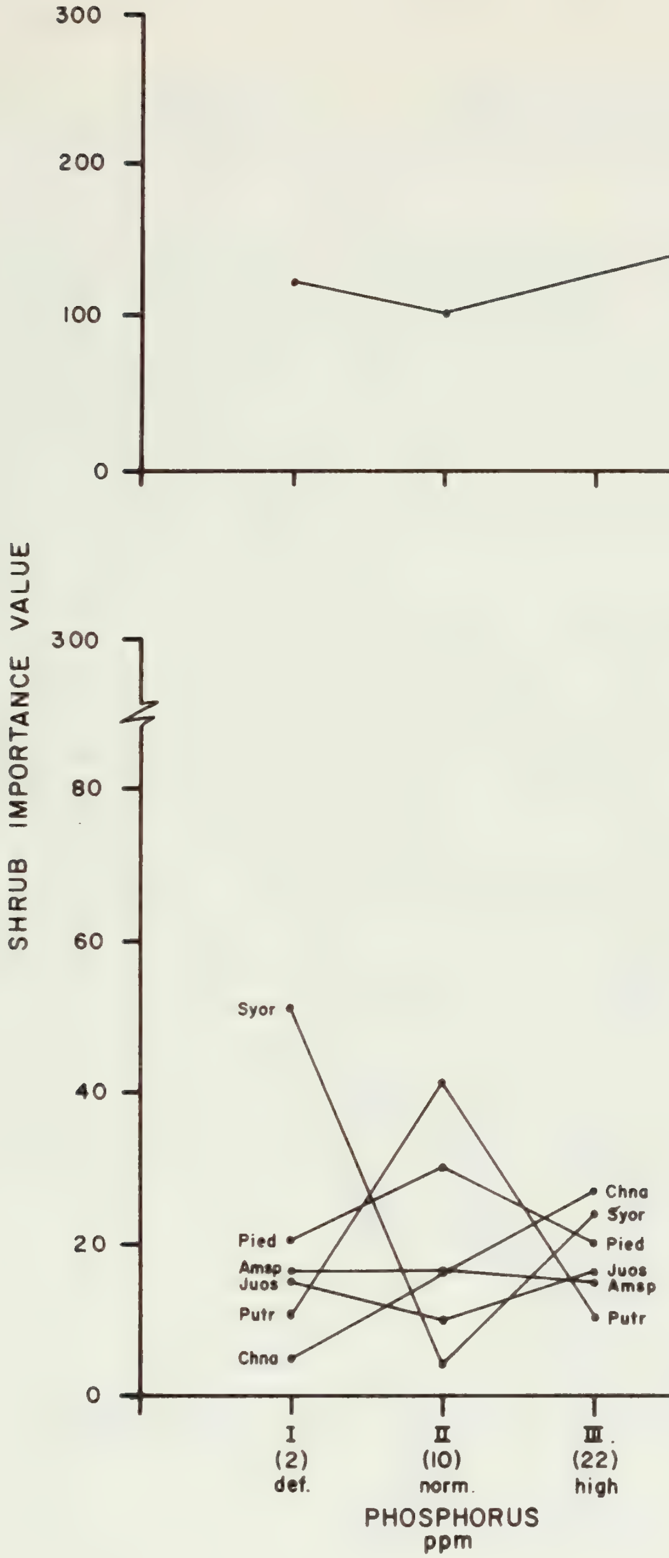


Figure V-54
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A PHOSPHORUS GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52. FOR EXPLANATION OF SPECIES ABBREVIATIONS.

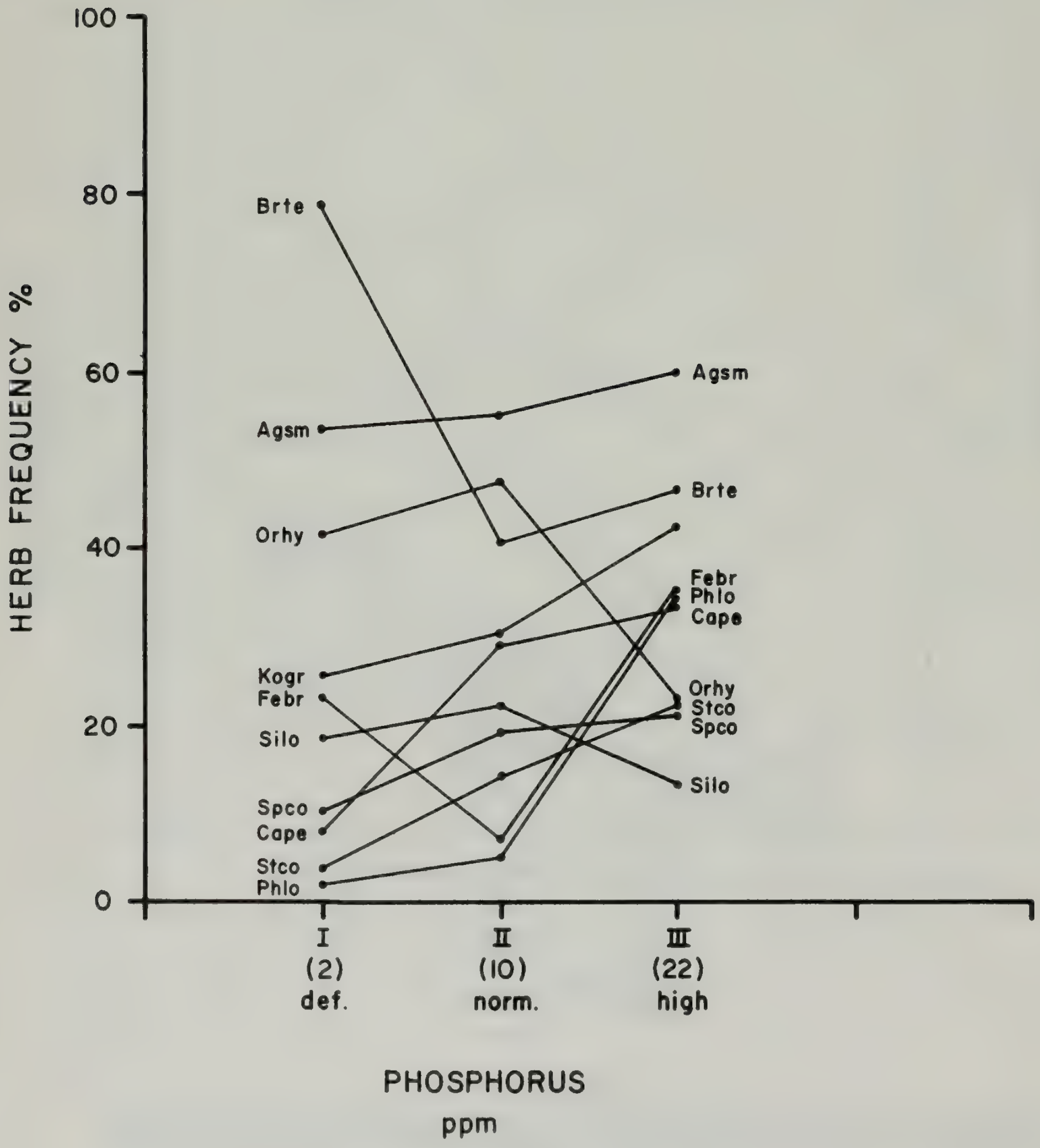


Figure V-55

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A PHOSPHORUS GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

relatively high importance of snowberry at deficient levels of phosphorus may relate to tolerance or to a general competitive interaction between this and other species. Rabbitbrush shows a steady increase in importance value with increasing phosphorus.

Herbs. Most of the grasses and forbs studied increase in frequency as phosphorus increases. The exceptions are cheatgrass (*Bromus tectorum*) and Indian ricegrass (*Oryzopsis hymenoides*). It is not clear if the relationship of cheatgrass to deficient phosphorus is direct, or if it operates through the influence of disturbed conditions which cause other herbaceous species to be absent from sites which are heavily grazed or otherwise disturbed. The decrease of Indian ricegrass at high phosphorus levels is also confusing. It is not clear in this case if the relationship is because of intolerance or general competition with other species. Western wheatgrass response is a reinforcing indication of its success in most stand types.

c. Potassium (Figures V-56 and 57)

Shrubs. The competitive relationship between several minor shrub species and big sagebrush is again apparent in the potassium gradient. The deficient potassium level appears to have little effect on the majority of shrub species studied; other levels of this nutrient have little effect. The feature which appears to control species response on this gradient is the importance value of big sagebrush. It is likely that the response of big sagebrush is a reaction to another nutrient, such as nitrate (which is high in the sites where sagebrush displays decrease in importance), or a reaction of the remaining shrub species to lowered concentrations of salts and sulphate which occur in levels I and III. Snowberry again seems to show a response related to competition with other minor shrub species.

Herbs. There are no strong trends occurring in herb frequency along this gradient. The lower frequencies of all species at deficient levels are expected. Cheatgrass and Junegrass show the only direct relationship - increasing in frequency as potassium increases.

d. Boron (Figures V-58 and 59)

Shrubs. This gradient illustrates another example of interspecific competition for nutrients other than the one displayed on the gradient. It also shows the tolerance of several shrub species to high levels of trace elements which are often considered to be toxic. The decrease in big sagebrush justifiably may be assigned to either an intolerance to boron or to a response to zinc deficiency (Figure V-74). The zinc deficiency in this case appears to be the result of high calcium concentrations existing in the sites where sagebrush decreases in importance. Increasing nitrate levels in sites where other shrub species increase in importance despite normally high to toxic levels of boron explain the trend.

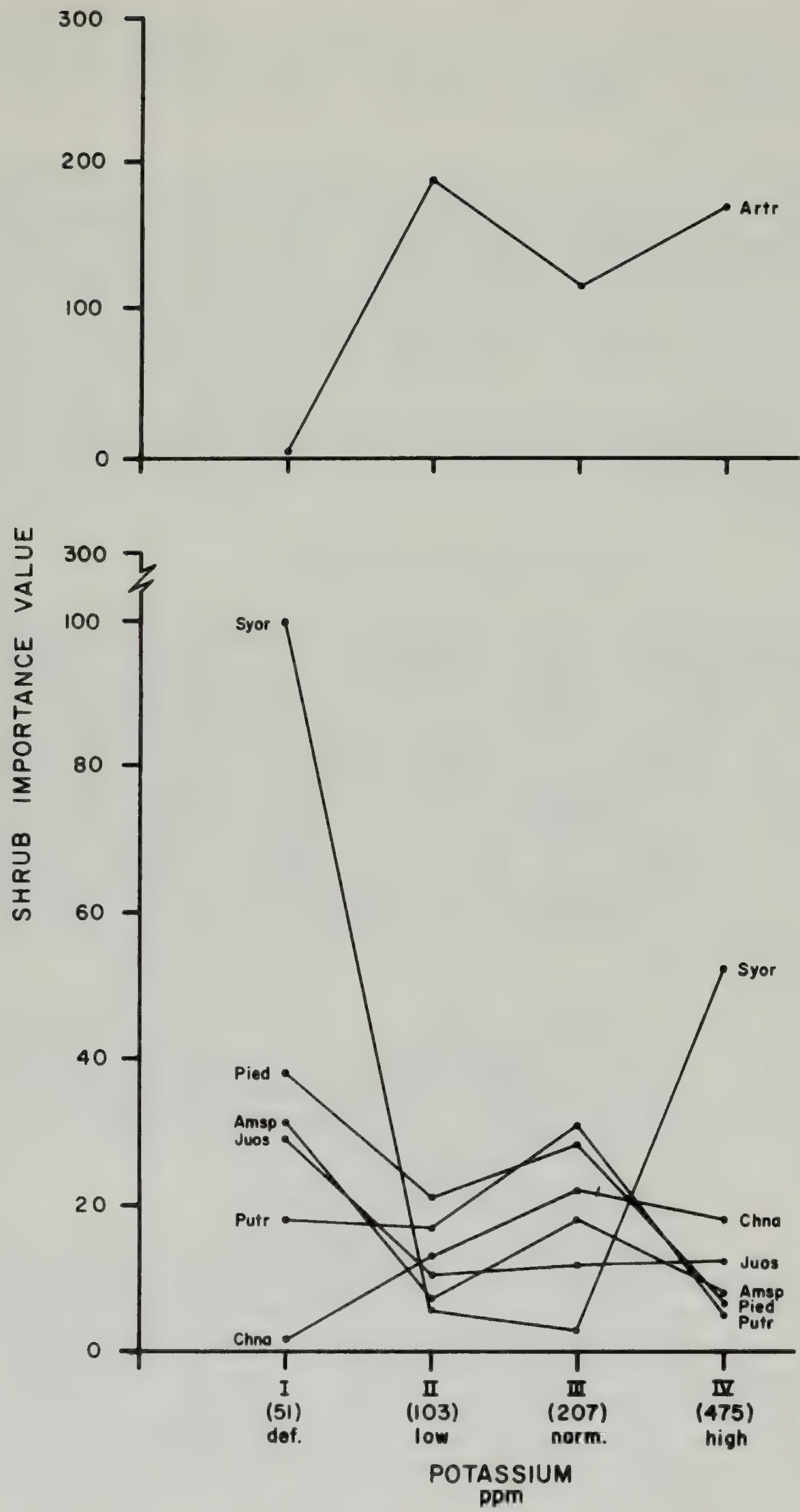


Figure V-56
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A POTASSIUM GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

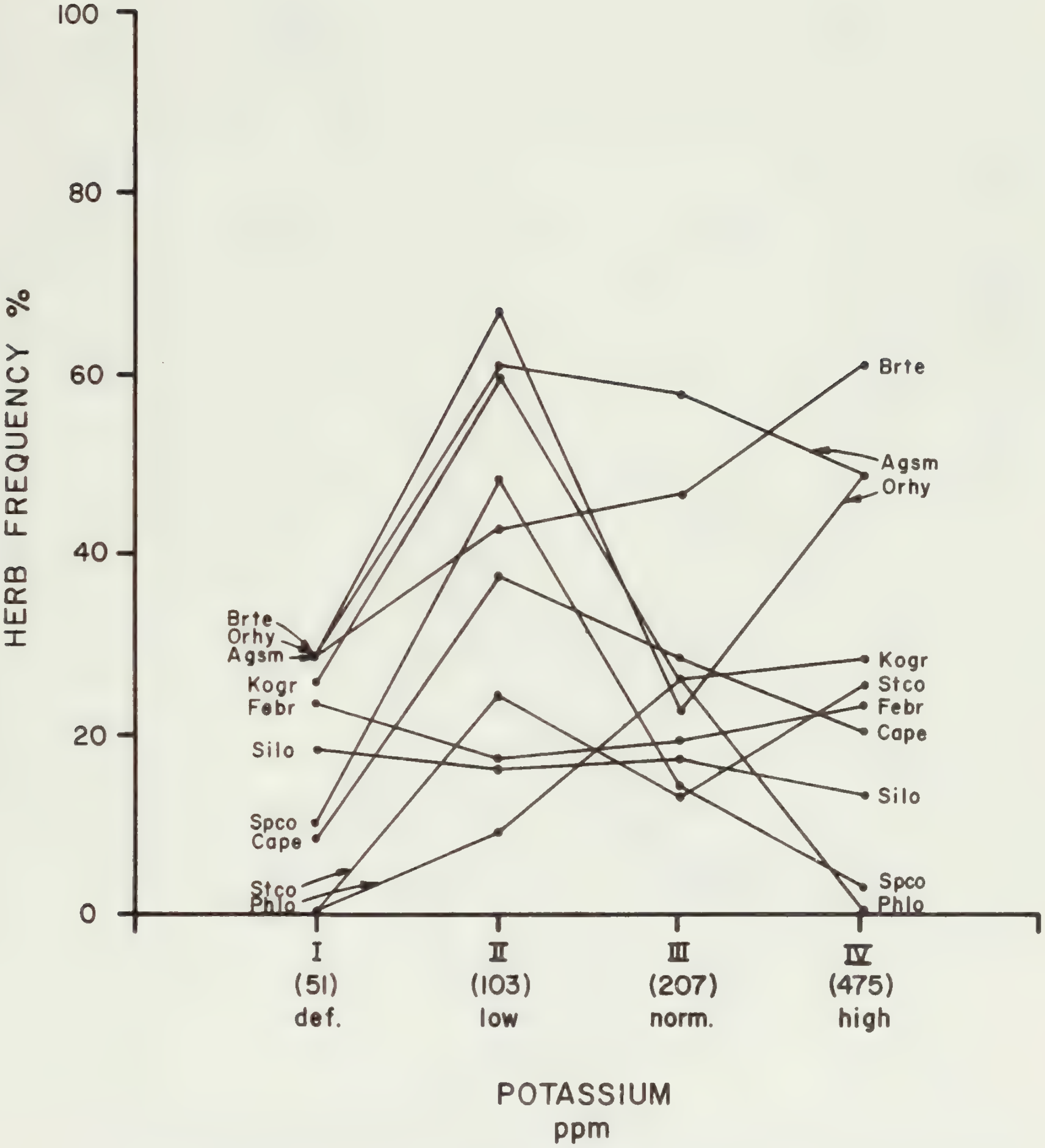


Figure V-57

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A POTASSIUM GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

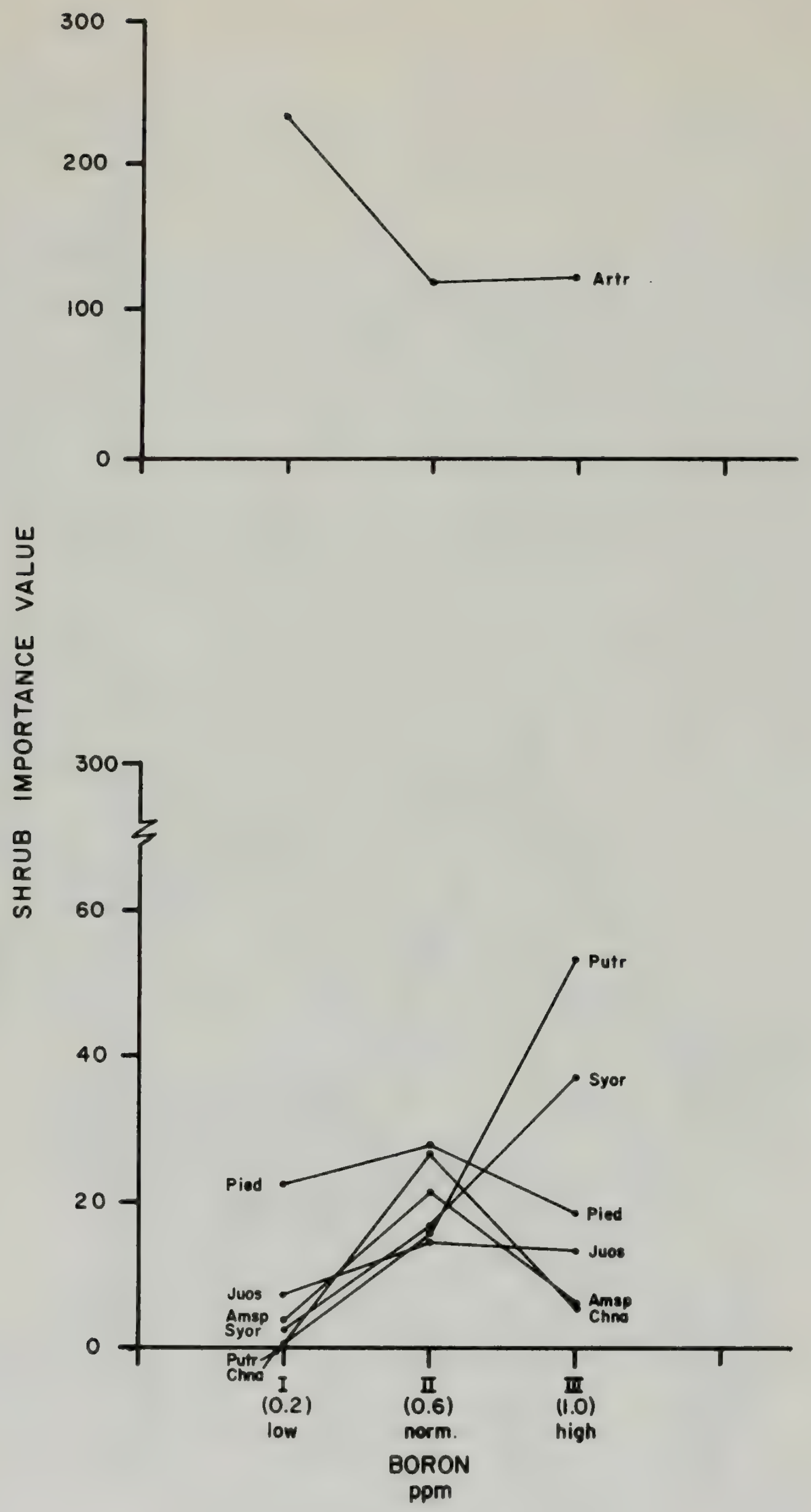


Figure V-58
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A BORON GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

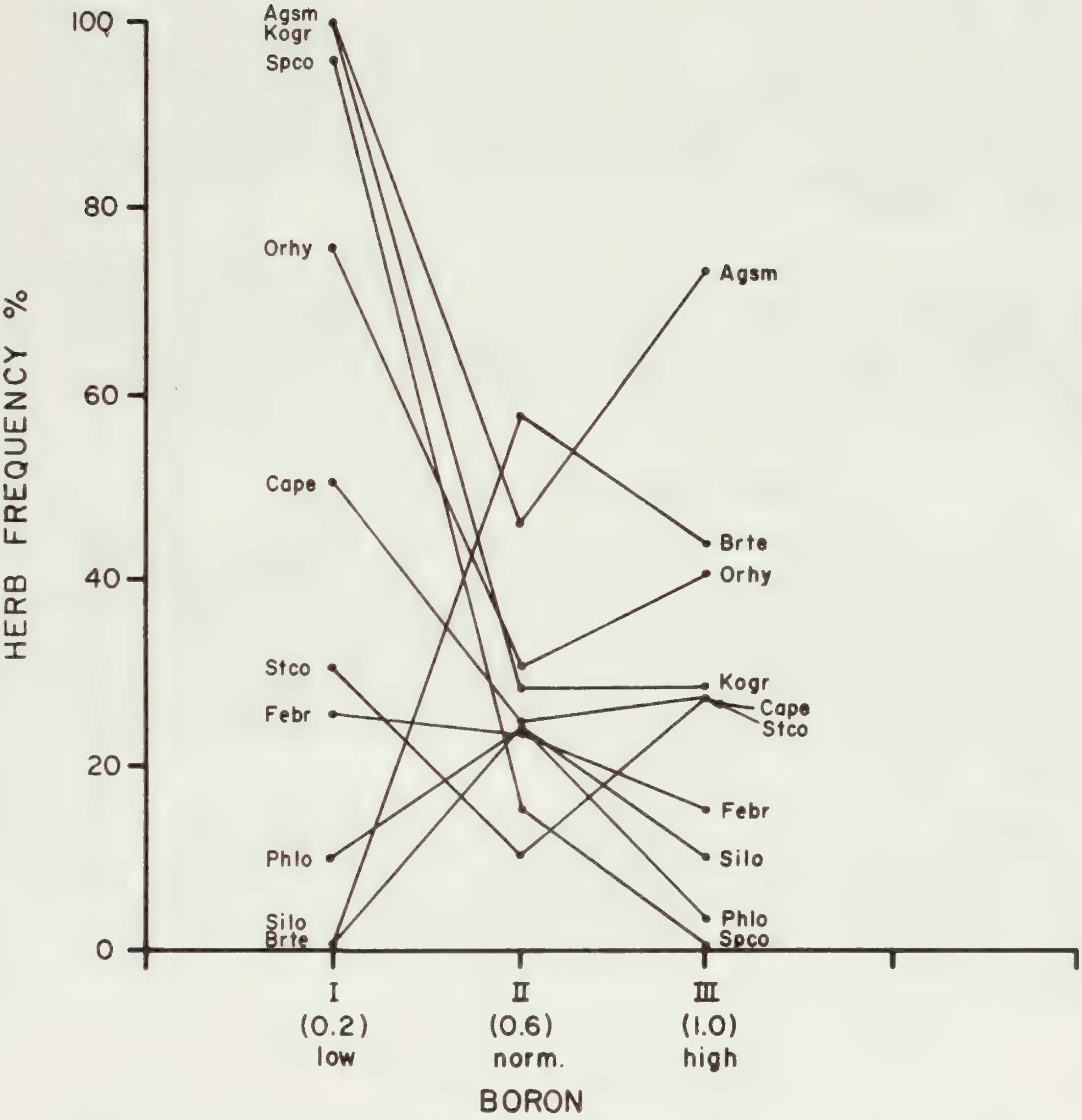


Figure V-59

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A BORON GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

Herbs. There are no direct responses of herbaceous species studied to increasing boron concentrations.

e. Calcium (Figures V-60 and 61)

Shrubs. The importance values for big sagebrush and rabbitbrush decrease along the gradient of increasing calcium. This appears, at least in the case of sagebrush, to relate to the interaction between zinc and calcium. Calcium is thought to limit the availability of zinc when the former is present at relatively high concentrations (Antonovics, et al., 1971; Brady, 1974). Figure V-74 illustrates the relationship between sagebrush and increasing zinc concentrations, implying a certain tolerance of sagebrush for zinc as well as a possible requirement which might be related to the high production rates of sagebrush discussed earlier in this section. All other shrub species increase in importance over this gradient.

Herbs. Grass species studied increase in frequency from normal-to-high calcium values, while the two forbs and one sedge studied decrease over the gradient. This relationship implies competitive utilization of calcium, but does not preclude the suggestions of other nutrient interactions, such as the influence of calcium on zinc as discussed above.

f. Copper (Figures V-62 and 63)

Shrubs. Big sagebrush demonstrates a direct increase in importance value with increasing copper concentrations. High copper levels are limiting to vegetation but are counteracted by high soil organic matter. This feature applies in some degree to the stands in which sagebur, reaches higher importance. It is also important to consider the high production rates of sagebrush in looking at this relationship. The variable response of other shrub species along this gradient suggests a complex interspecific competition.

Herbs. The response of the herbaceous species studied to increasing copper concentrations illustrates the intolerance of most grasses and forbs to high copper levels. The increase in cheatgrass at high copper concentrations shows this species tolerance for stress situations; scarlet globe mallow (Sphaeralcea coccinea) has a similar response pattern.

g. Iron (Figures V-64 and 65)

Shrubs. Five of the seven shrub species studied show an increase in importance value from low to normal concentrations of iron but declining as iron reaches high levels. The remaining two species, snowberry and big sagebrush, differ. Snowberry decreases in importance at high levels but shows high importance values at low iron concentrations. The explanation for this response appears to be the low level of sage-

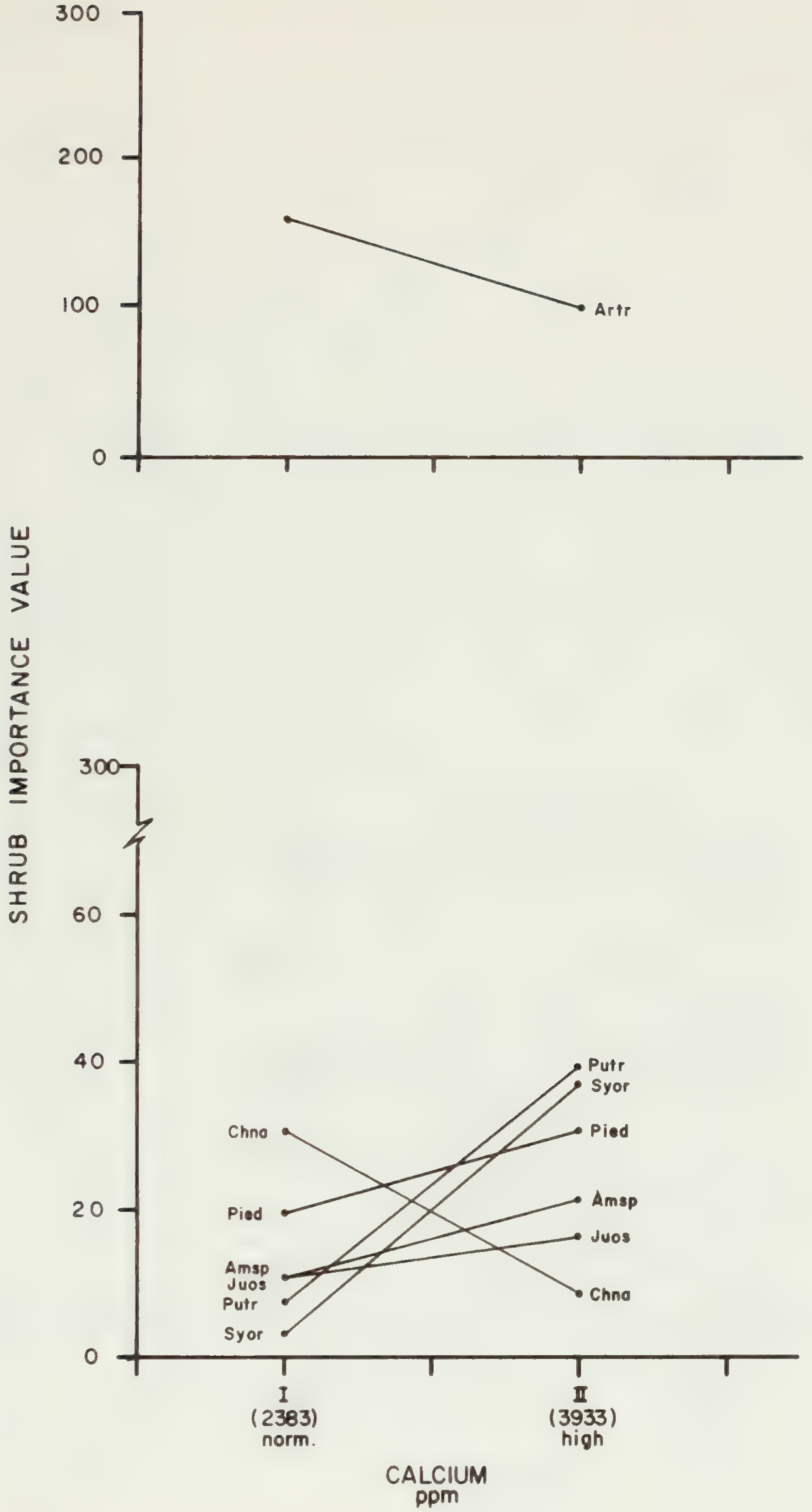


Figure V-60
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A CALCUIM GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

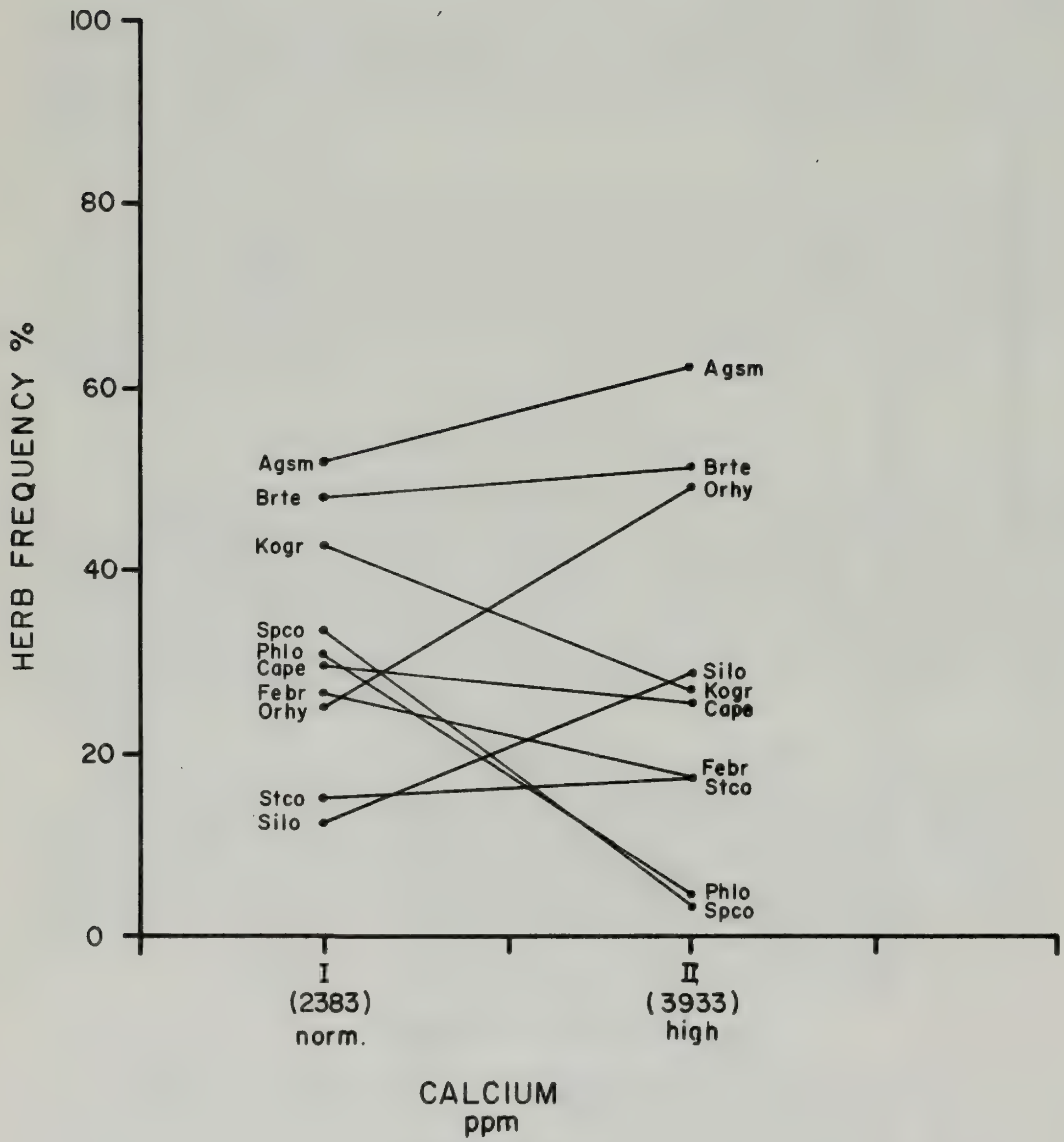


Figure V-61

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A CALCIUM GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

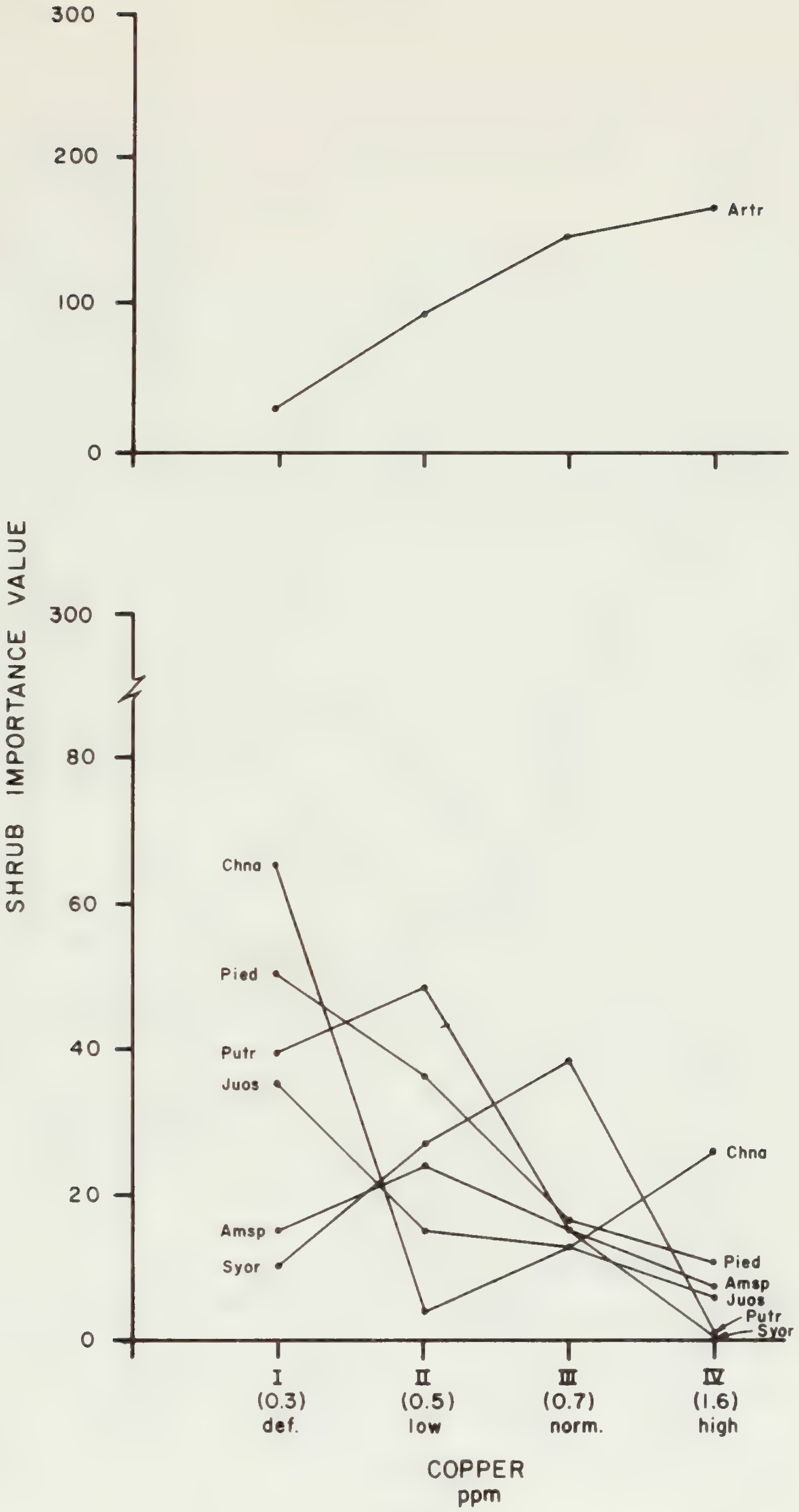


Figure V-62
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A COPPER GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

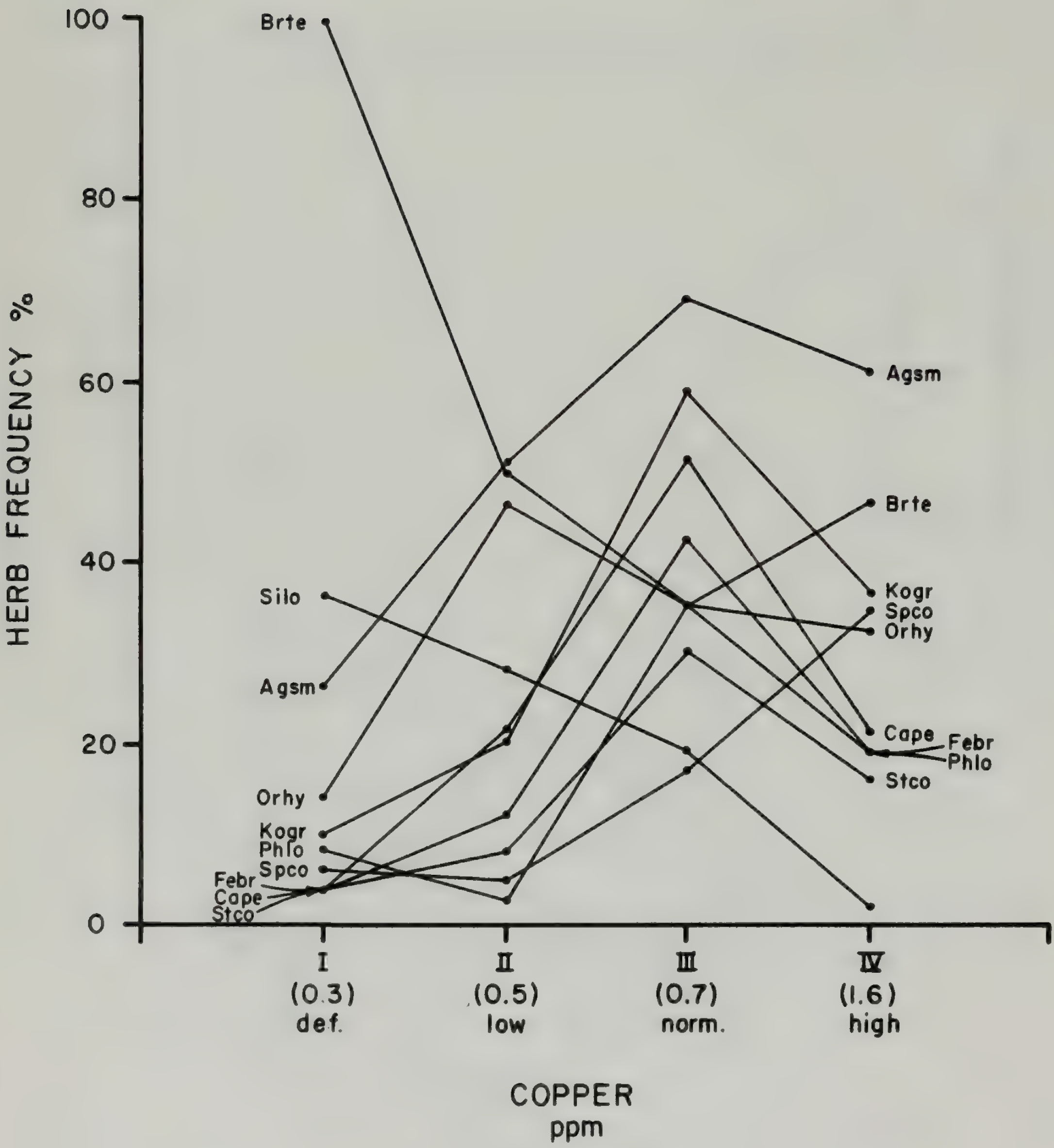


Figure V-63

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A COPPER GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

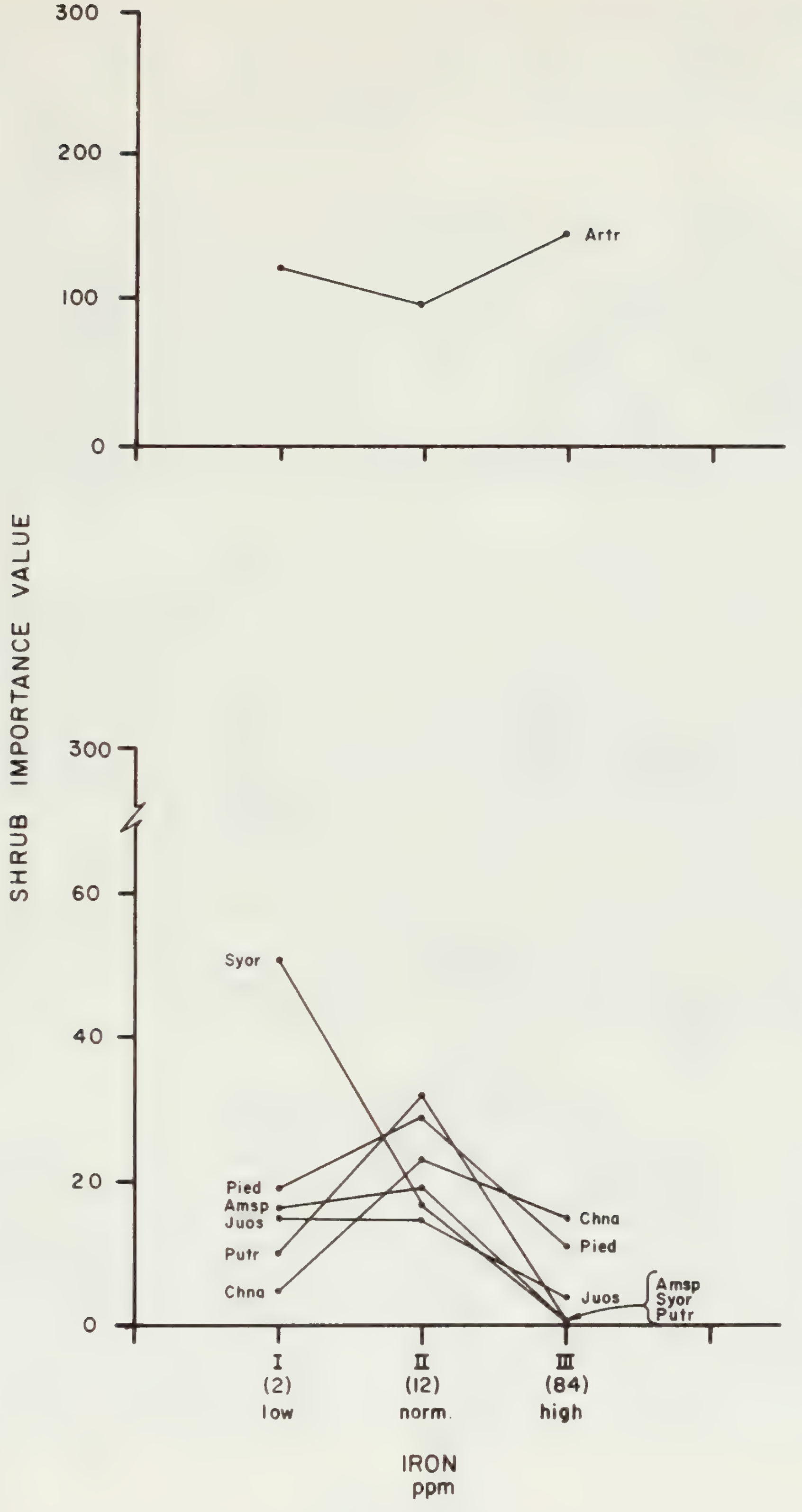


Figure V-64
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO AN IRON GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

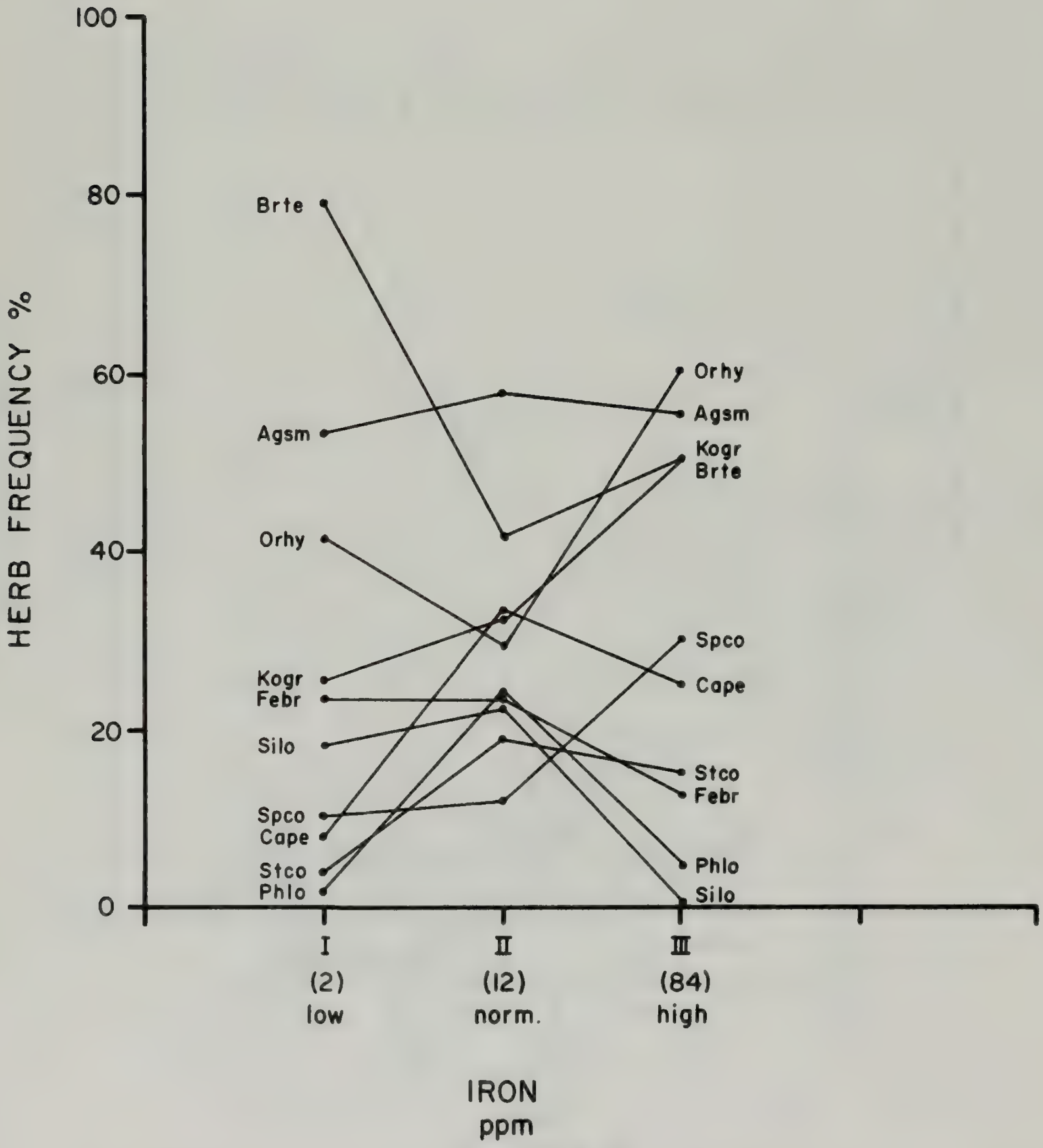


Figure V-65

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO AN IRON GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

brush in sites where low iron levels occur coupled with random seedling survival in other shrub species. The response of sagebrush to this gradient corresponds with its response to other trace element gradients. There is also an apparent relationship involving nitrate and calcium, i.e., sagebrush tends to decrease in stands where these nutrients are high (Figures V-52 and 60).

Herbs. The majority of the herbaceous species respond to increasing iron in a manner similar to the shrub response, i.e., increasing from low-to-normal values, declining at high levels. Junegrass and scarlet globe mallow increase over the entire gradient. This response correlates well with the increasing occurrence of these two species in chained rangeland sites and upland sagebrush communities. Cheatgrass and Indian ricegrass show high frequency at low levels, lower frequency at normal levels, and high frequency at high levels. This response implies a competitive relationship with the remaining species which compete well at normal levels of this nutrient.

h. Magnesium (Figures V-66 and 67)

Shrubs. Big sagebrush increases with increasing magnesium concentrations. The remaining species decrease in importance from normal-to-high concentrations. This and other nutrient responses involving sagebrush (i.e., potassium and phosphorus) indicate that sagebrush exerts a competitive advantage in the assimilation of nutrients while at the same time displaying a tolerance for levels of soil chemicals which are termed as detrimental or limiting to vegetation in general. It is probable that the tolerance for toxic concentrations enables the sagebrush to reach population densities which are directly related to its nutrient uptake.

Herbs. The majority of the herbaceous species shown increase in frequency from low-to-normal magnesium concentrations, decreasing at high levels. Cheatgrass, Indian ricegrass, Junegrass and scarlet globe mallow are exceptions all increasing at high magnesium concentrations.

i. Manganese (Figures V-68 and 70)

Shrubs. The response of sagebrush to this gradient, together with the behavior of other shrub species,implies the influence of other soil nutrients. Analysis of nitrate and potassium levels (Figures V-52 and 56) indicate that low potassium levels and high nitrate may be involved. Other gradients have shown that sagebrush increases as potassium increases and decreases as nitrate increases. Similarily, the low importance of other shrubs at normal manganese concentrations corresponds with decreasing phosphorus. Sulphate concentrations in these same sites relates directly to increasing and decreasing importance of sagebrush, and, inversely, to changes in importance values of other shrub species.

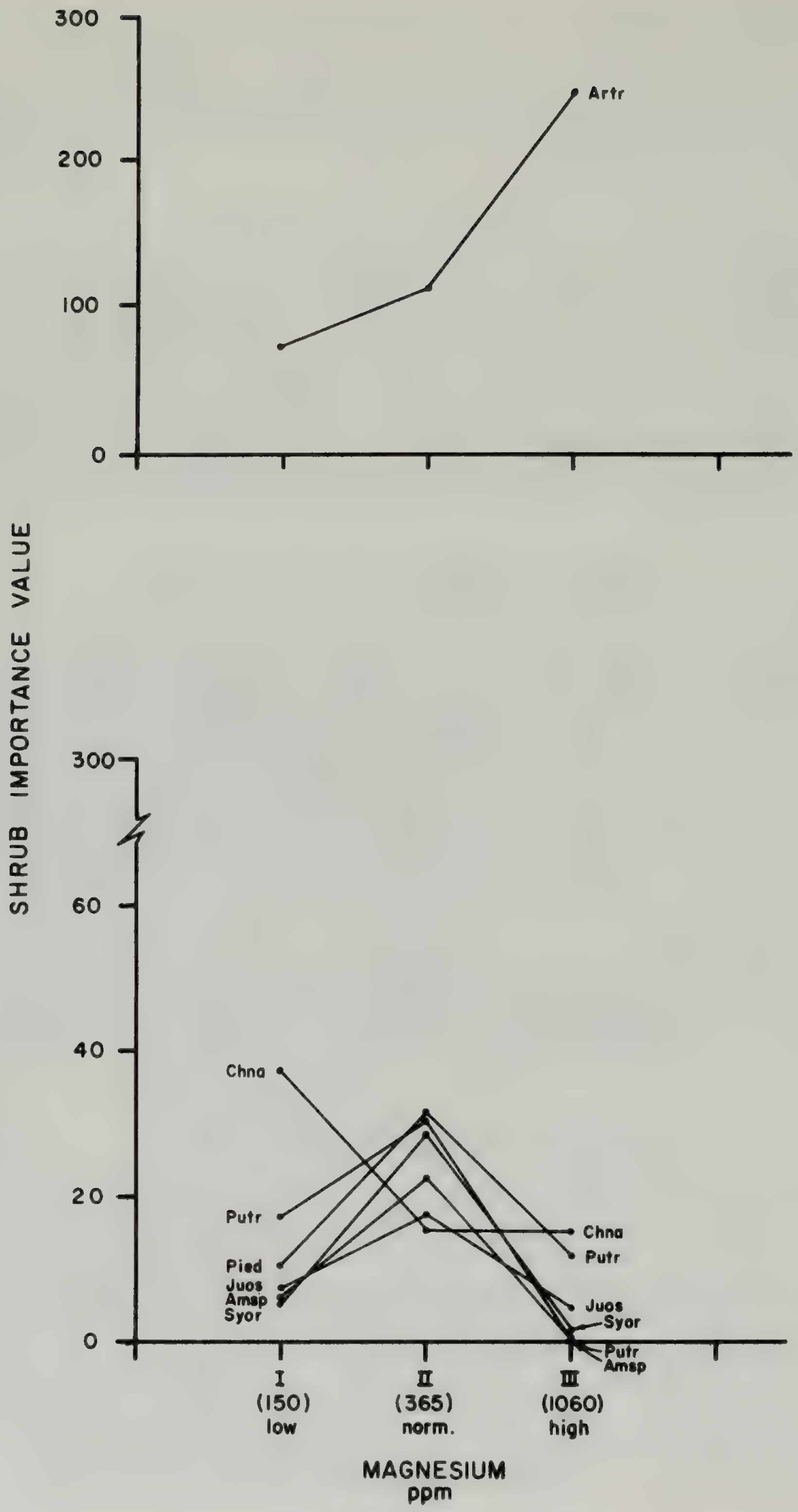


Figure V-66
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A MAGNESIUM GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

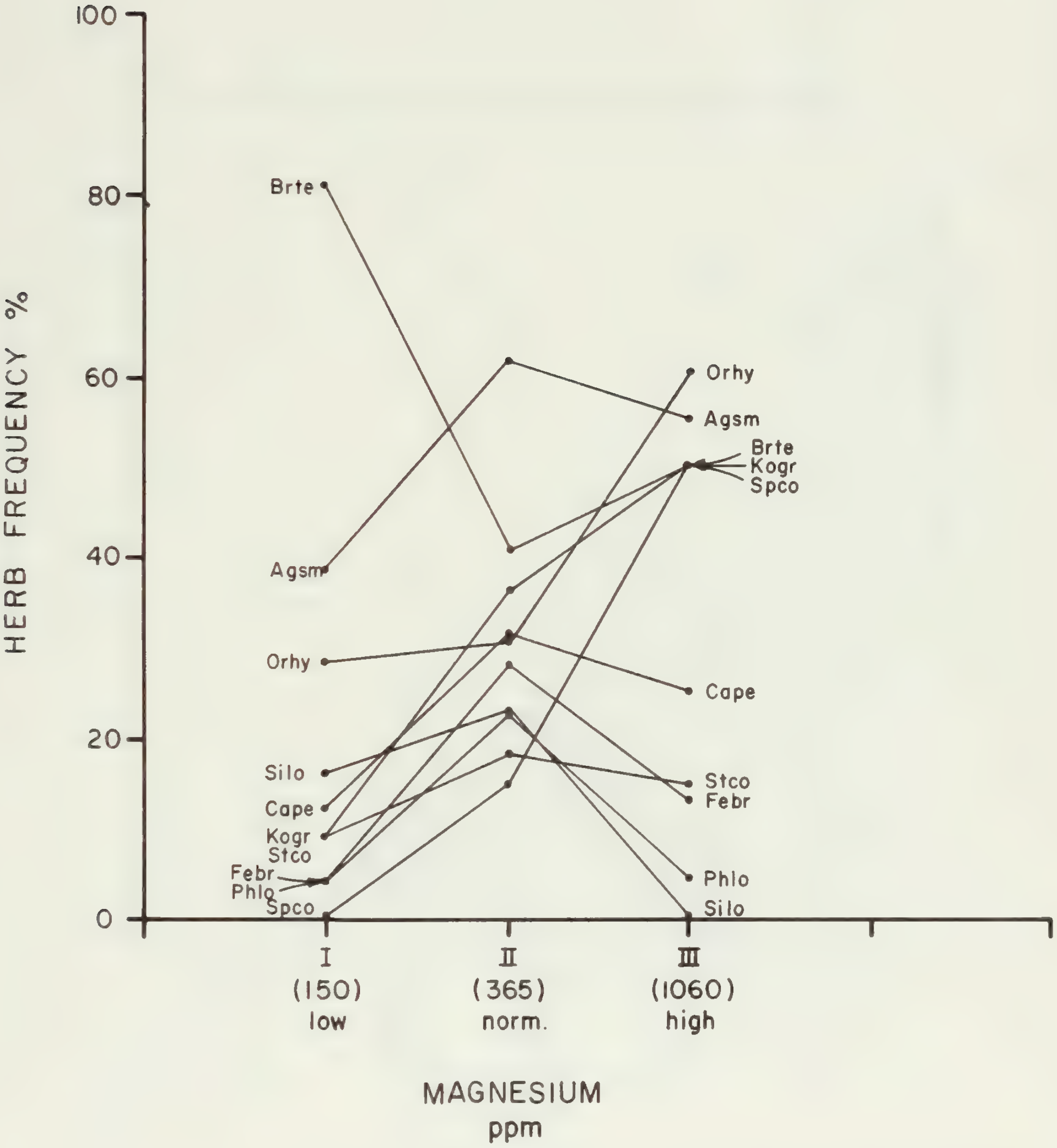


Figure V-67

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A MAGNESIUM GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

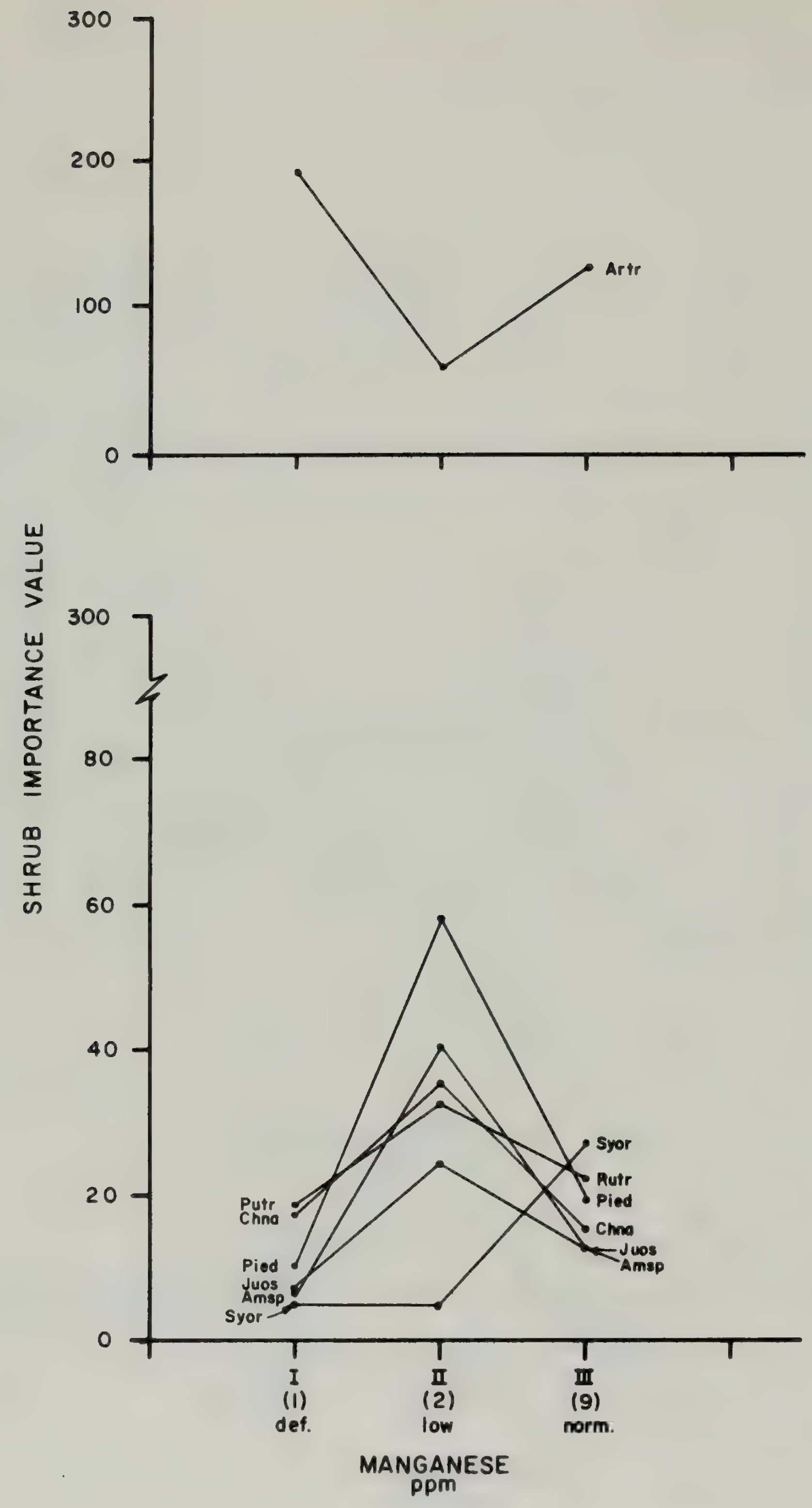


Figure V-68
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A MANGANESE GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

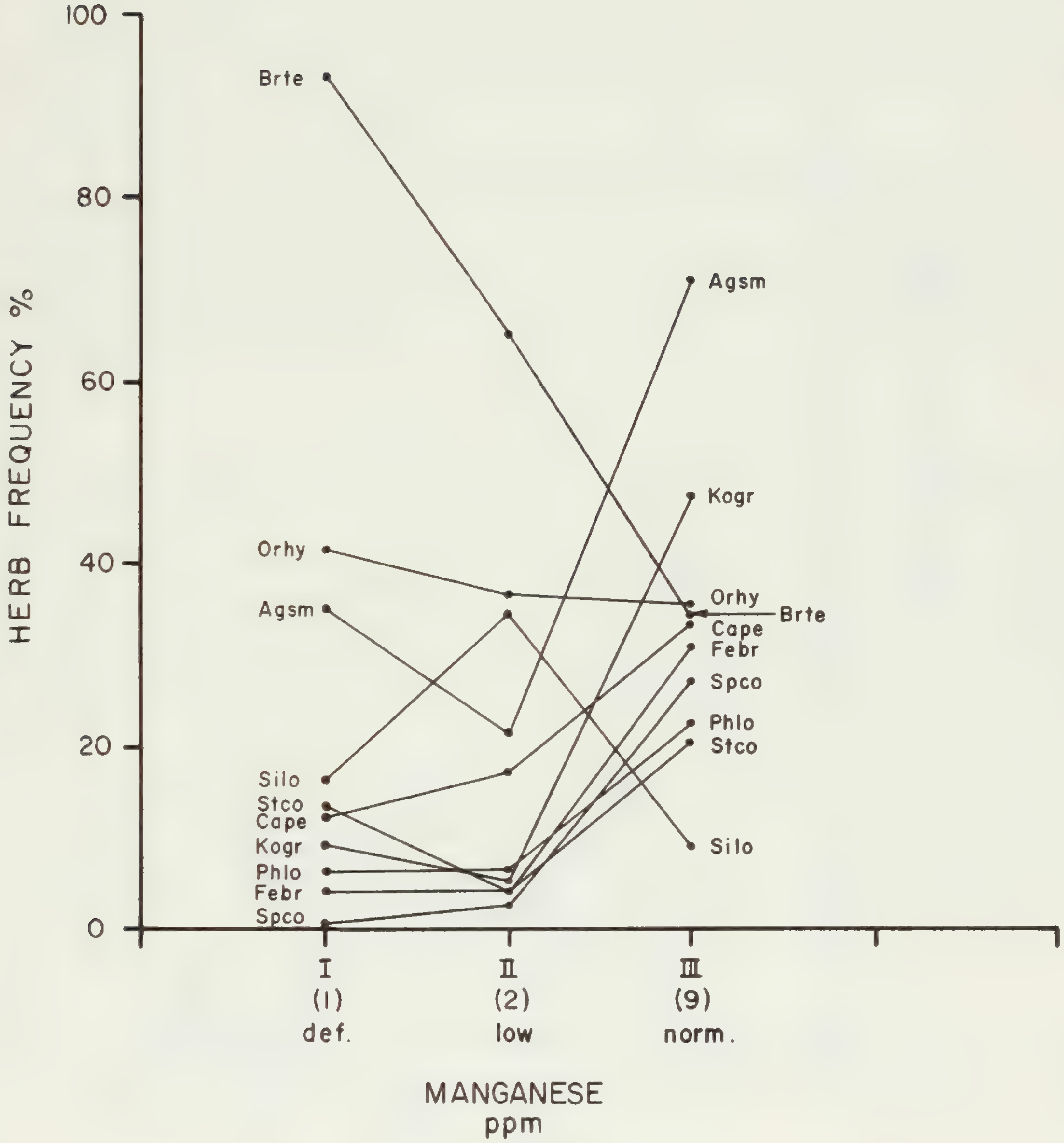


Figure V-69

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A MANGANESE GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

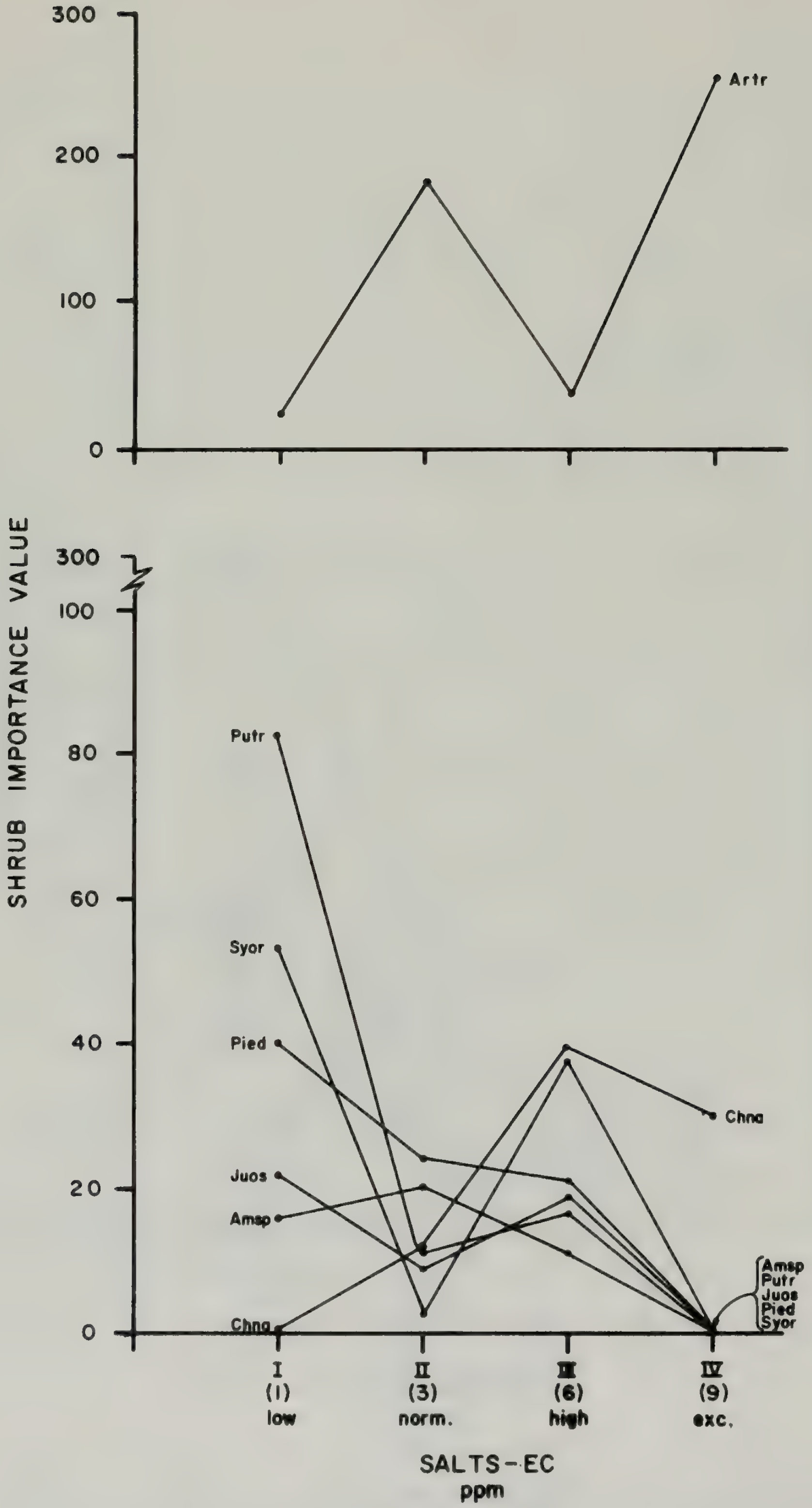


Figure V-70
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A TOTAL SALTS (EC) GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

Herbs. Cheatgrass and Indian ricegrass are the exceptions to herbaceous-species increasing frequencies with increasing manganese. These two species decrease in frequency over the gradient.

j. Total Salts (Electrical Conductivity) (Figures V-70 and 71)

Shrubs. Big sagebrush and rabbitbrush respond to excessive salt concentrations with increasing importance value. All other species studied decrease at this concentration. The remainder of the species are varying through seemingly random increases and decreases which are ostensible responses to competition for other nutrients. For example, other gradients show a decline in the importance value of sagebrush with high nitrate concentrations. Comparisons of the sites used in these gradients indicate a correspondence between low sagebrush importance on the salt gradient and high nitrate.

Herbs. Cheatgrass and Indian ricegrass display increasing frequencies with increasing salt concentrations. All other herbaceous species studied respond to high and excessive salt concentrations with decreasing frequency. The increase of cheatgrass with salts is an implied tolerance which is supported by other known halophytes in the genus Bromus, noteably Bromus japonicus (Waisel, 1972).

k. Sulfate - Sulfur (Figures V-72 and 73)

Shrubs. The response of rabbitbrush to excessive sulfate concentrations is of note in this gradient and indicates a tolerance under these conditions. The low importance of rabbitbrush at high sulfate levels, on the other hand, appears to be the result of competition with sagebrush. All other species have low importance at excessive levels; the majority of these species have low importance at high concentrations also. The relationship between big sagebrush and other shrub species can be noted. A possible explanation for this relationship might once again be high nitrate levels which correspond with low sagebrush importance.

Herbs. Most of the herbaceous species studied increase at high sulfate concentrations. Cheatgrass and Indian ricegrass decrease at these high levels, but increase at excessive levels. The tolerance of cheatgrass is supportable, but in the case of Indian ricegrass it is better to avoid interpretations which suggest that this species is salt-tolerant since there is no research to support this conclusion.

l. Zinc (Figures V-74 and 75)

Shrubs. The response of shrub species along the zinc gradient indicates that interspecific competition for other nutrients is a greater influence than is zinc alone. Note, however, the increase of big sagebrush at high levels of zinc.

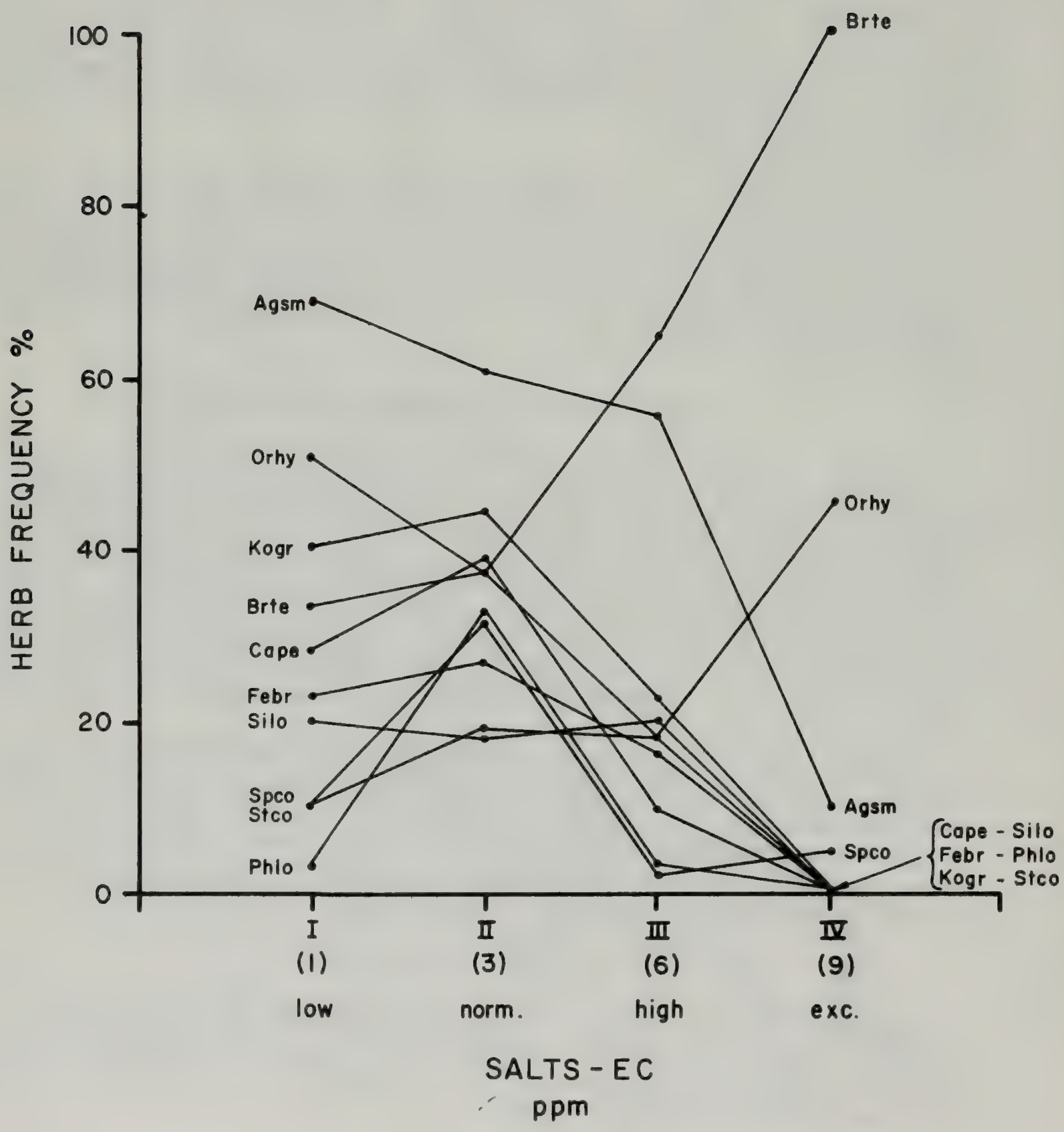


Figure V-71

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A TOTAL SALTS (EC) GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

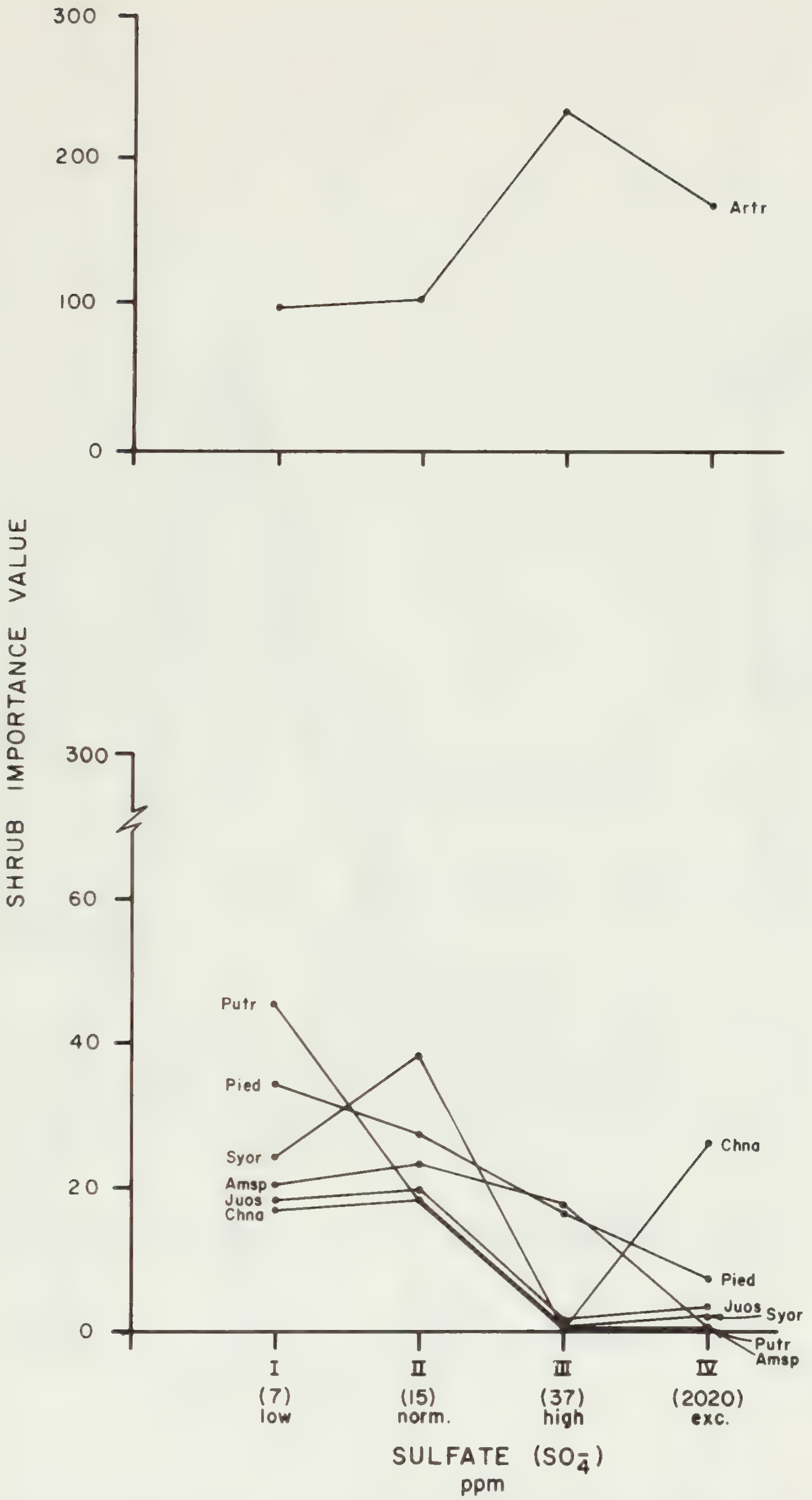


Figure V-72
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A SULFATE-SULFUR GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

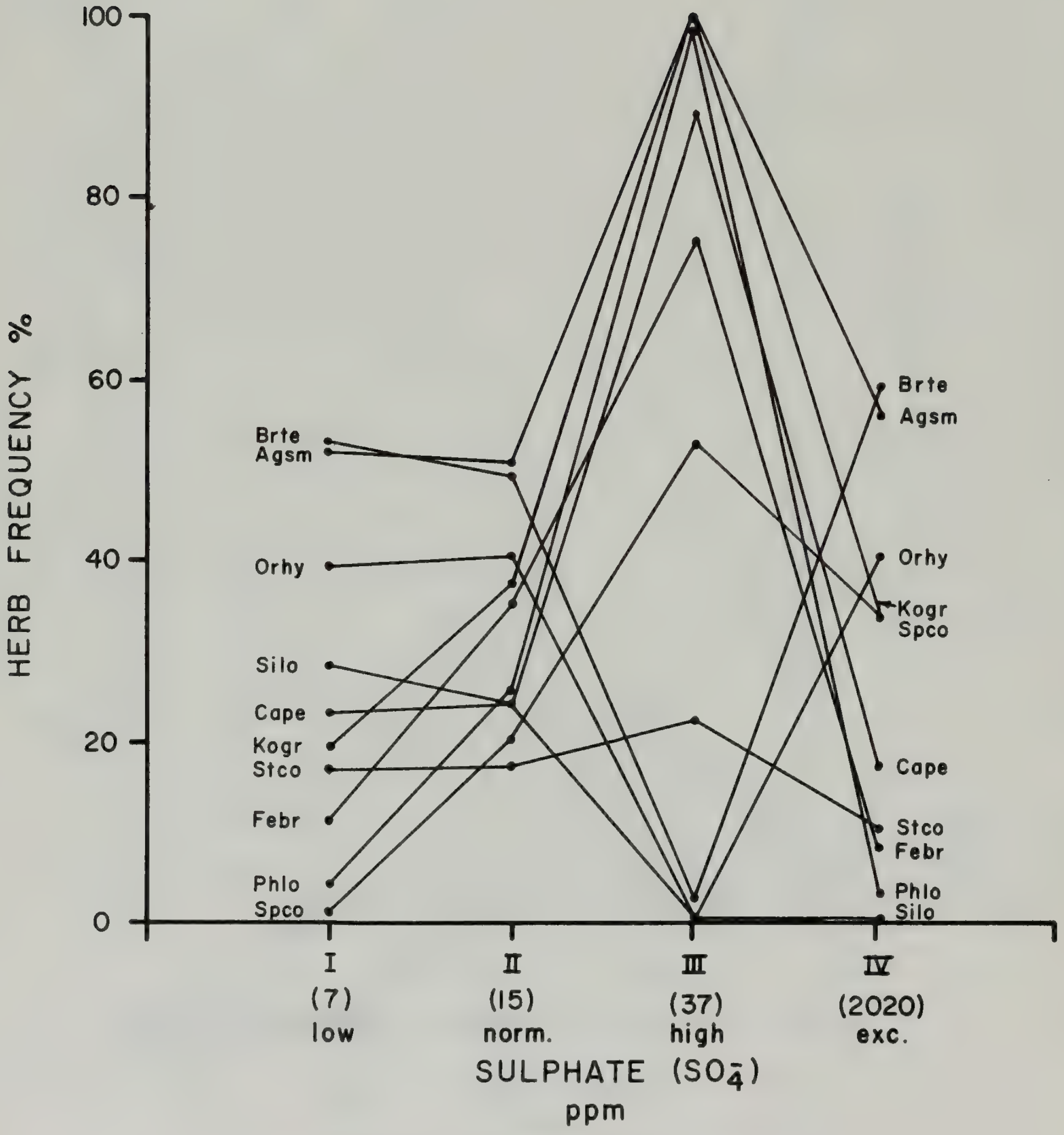


Figure V-73

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A SULPHATE-SULPHUR GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

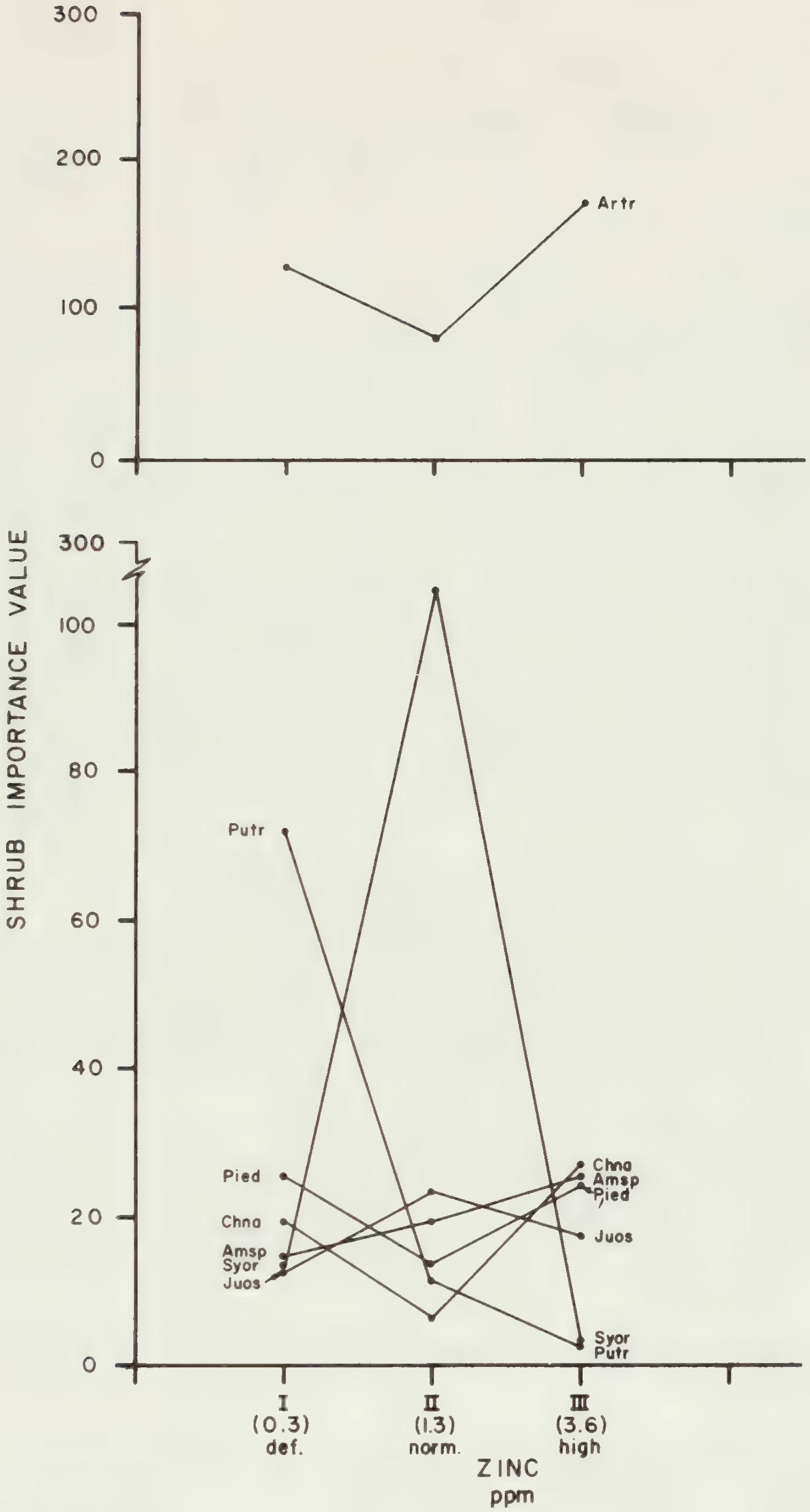


Figure V-74
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A ZINC GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

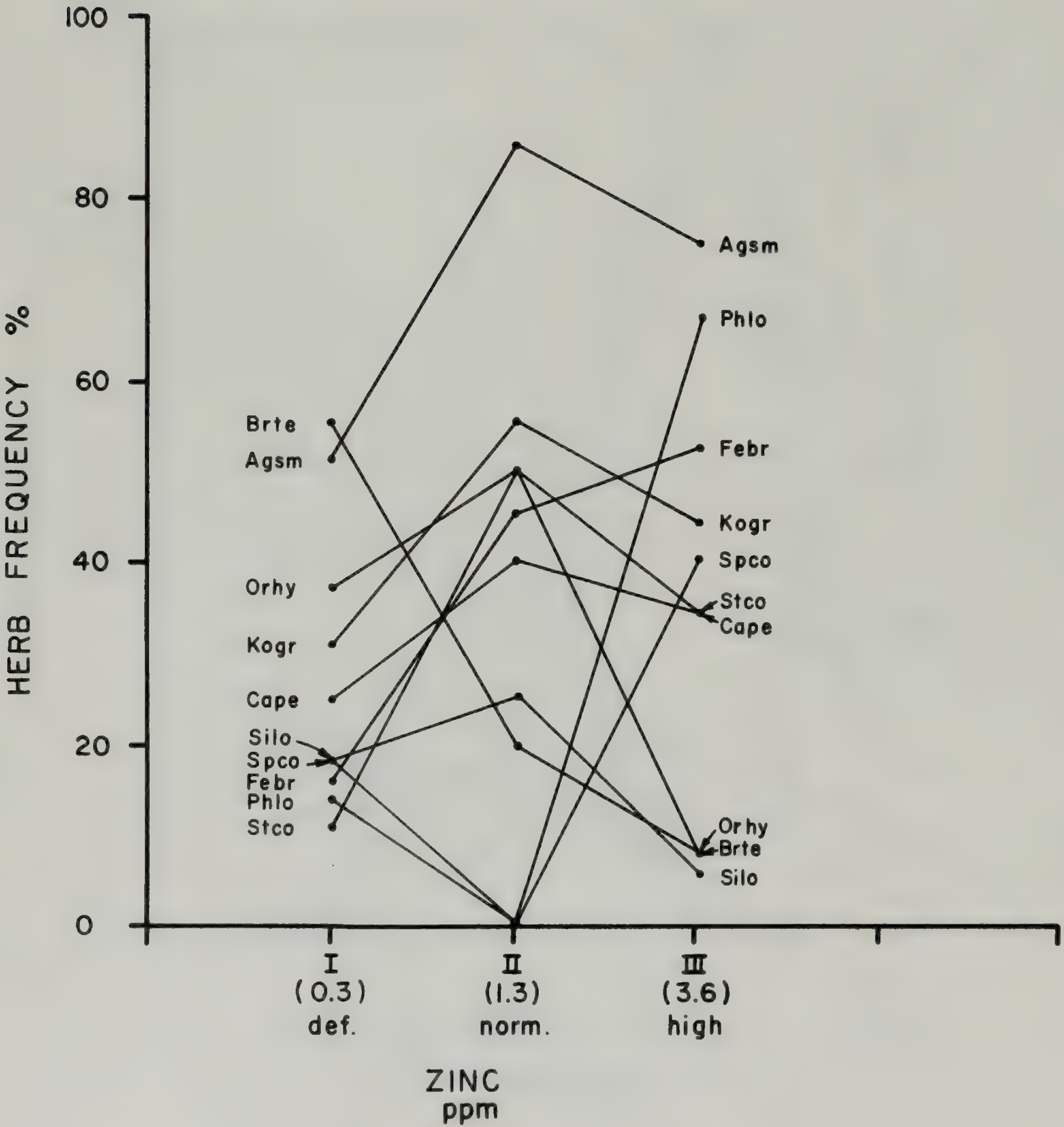


Figure V-75

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A ZINC GRADIENT IN THE SOIL SURFACE LAYER.
SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

Herbs. Herbaceous-species response reflects a competitively controlled scheme along this gradient as well. Forbaceous species respond to high zinc concentrations with increasing frequency. For the most part, however, other factors appear to have strong influence.

m. Field Capacity (15 Bar) (Figures V-76 and 77)

Shrubs. Rabbitbrush decreases in importance as field capacity increases. Sagebrush has high importance at both low and high values of field capacity. The lower importance of sagebrush at levels in between appear to be related to competition with other shrub species for nutrients. It is interesting to note that low field capacity and high salt concentrations are strongly correlated. In any case the response of the species studied indicates the interaction of factors other than field capacity alone.

Herbs. Cheatgrass decreases in frequency as field capacity increases. This response reenforces the tolerance of cheatgrass for stress conditions and indicates its lowered invasion potential in established communities. Indian ricegrass also decreases from low-to-high field capactiy. This response may account for Indian ricegrass success in stands which occupy dry south-facing slopes and for its tolerance of toxic elements such as salts and sulphate on sites where these elements are of limited availability, i.e., not in solution in the uppermost soil layer.

n. Soil Moisture (Figures V-78 and 79)

Shrubs. Sagebrush generally increases in importance with increasing soil moisture. The response of other shrub species is not as direct but importance value generally increases at high soil moisture. Pinyon pine demonstrates a tolerance for low soil moisture and does not appear to compete well with other species at high soil moisture.

Herbs. Cheatgrass, Indian ricegrass and squirreltail (*Sitanion longifolium*) respond variably to the gradient of increasing soil moisture. All other herbaceous species studied increase in frequency from low-to-higher soil moisture. The decline of these species and the increased frequency of cheatgrass, Indian ricegrass and squirreltail at high levels is possibly a result of harsh-site conditions.

o. Interspecific Competition (Figures 80 and 81)

The most significant complication brought out in the above discussion of soil-vegetation interrelationships has been the effect of interspecific competition for nutrients. Additional analyses are required to refine the understanding of these specific effects. Figure V-80 illustrates the relative importance of the shrub species studied in the five stand types used in the above gradient analysis. This figure reenforces the preliminary interpretations of competitive interactions discussed above. The competitive relationship between big sagebrush and other species, particularily snowberry, are clearly shown. The general increase of sagebrush and rabbitbrush on sites characterized

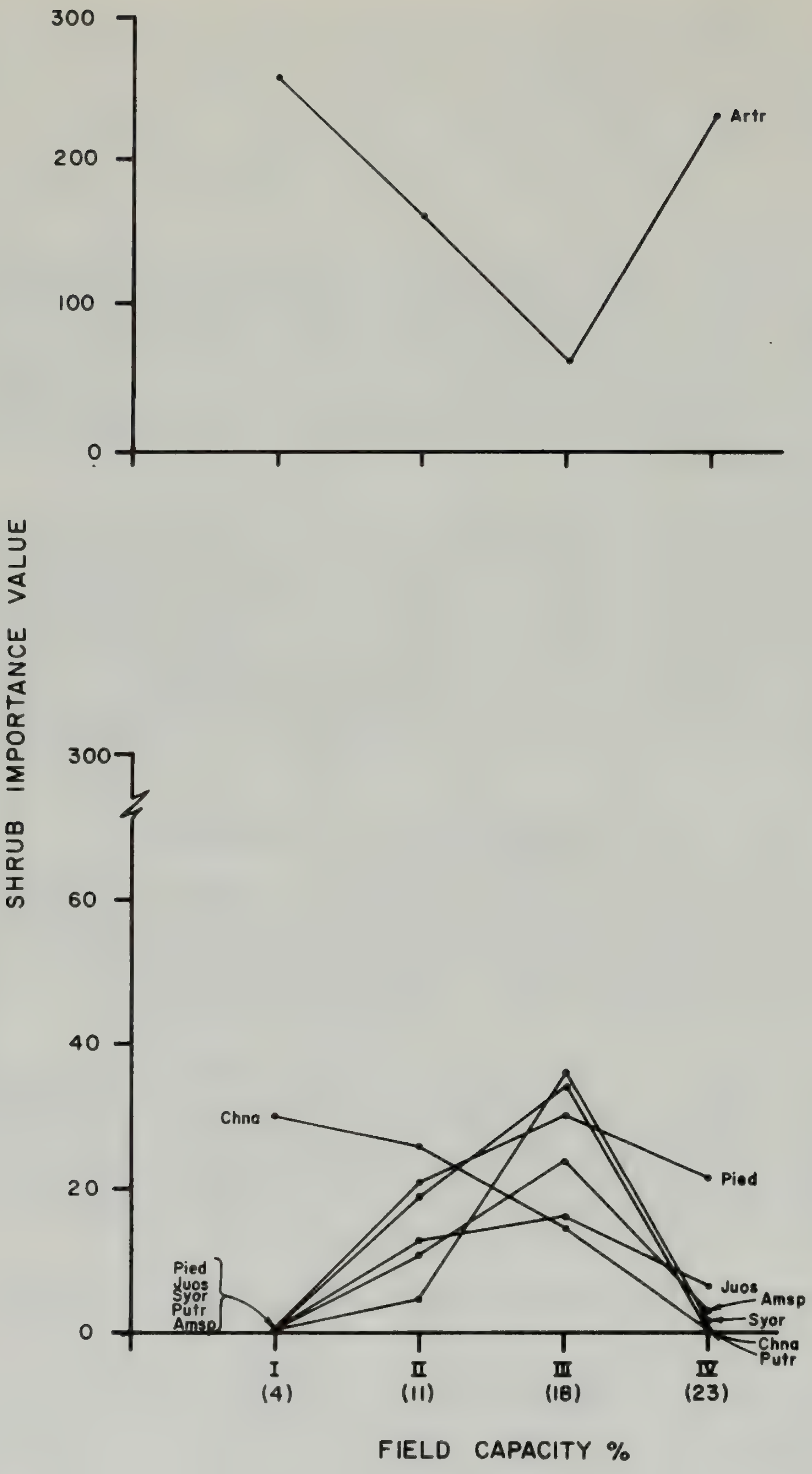


Figure V-76
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A FIELD CAPACITY (15 BAR) GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

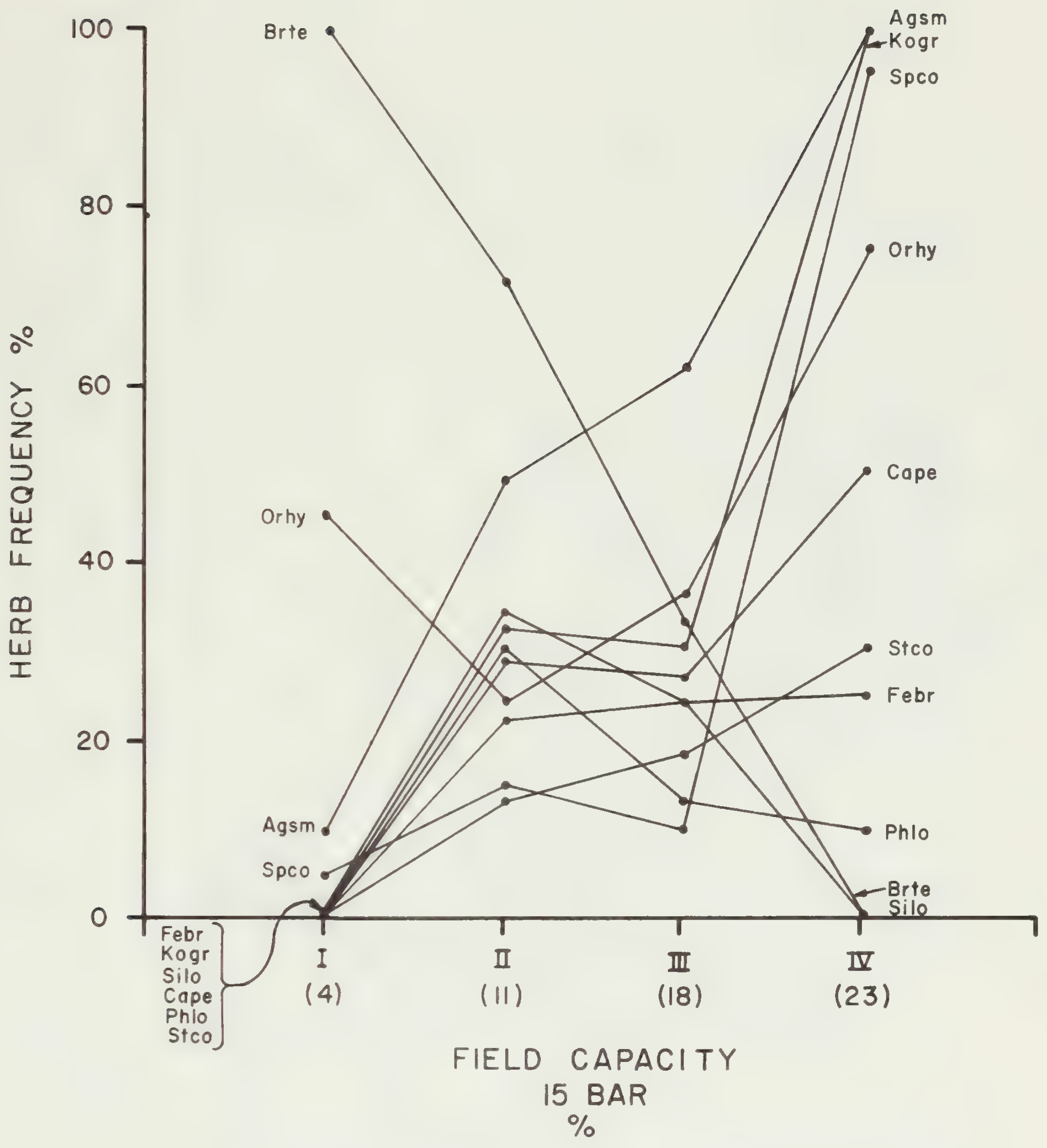


Figure V-77

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A FIELD CAPACITY (15 BAR) GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

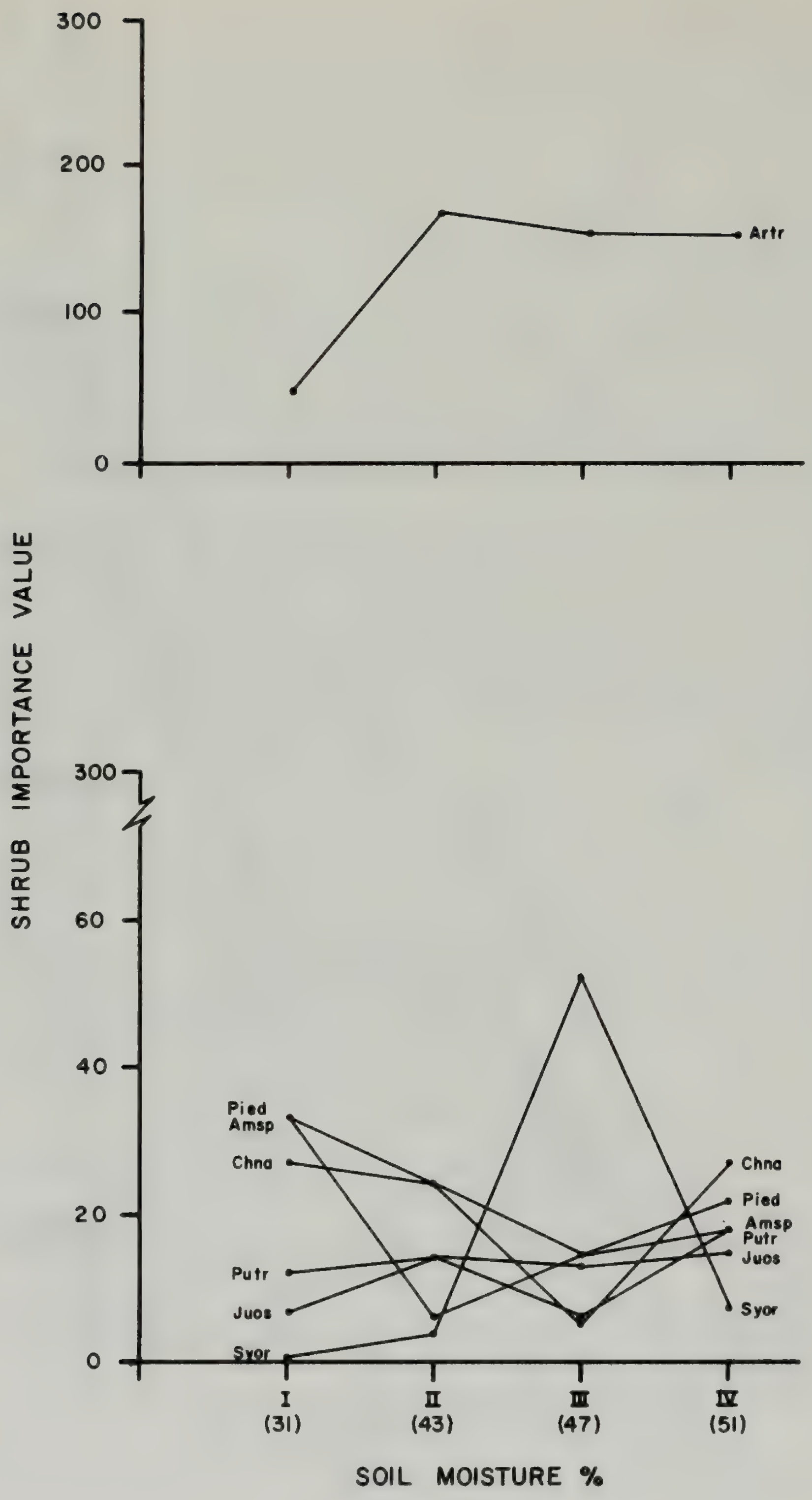


Figure V-78
RELATIONSHIP OF IMPORTANCE VALUE FOR SEVEN SHRUB SPECIES TO A PERCENT SOIL MOISTURE GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

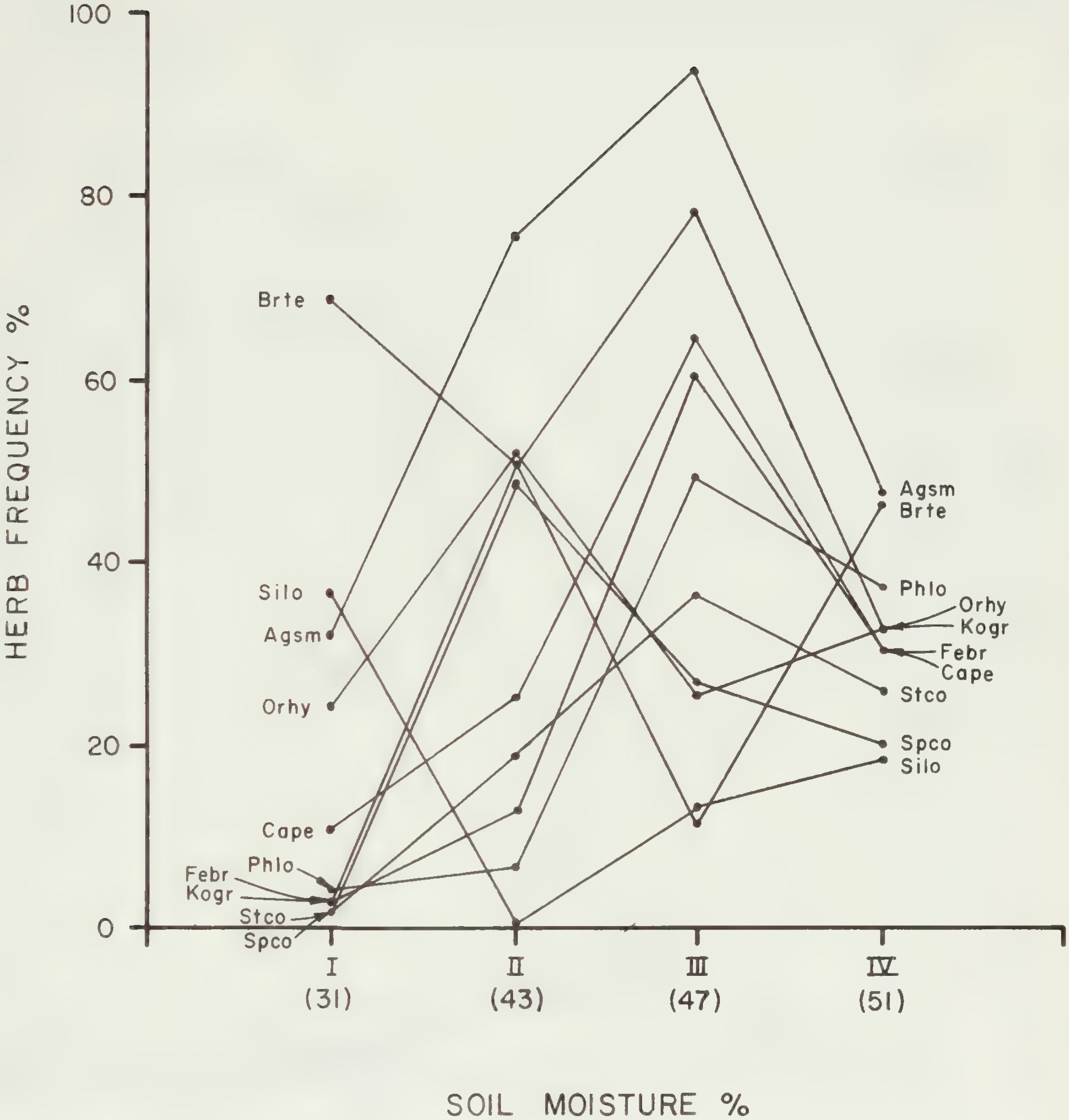


Figure V-79

RELATIONSHIP OF FREQUENCY VALUE FOR TEN HERBACEOUS SPECIES TO A PERCENT SOIL MOISTURE GRADIENT IN THE SOIL SURFACE LAYER. SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

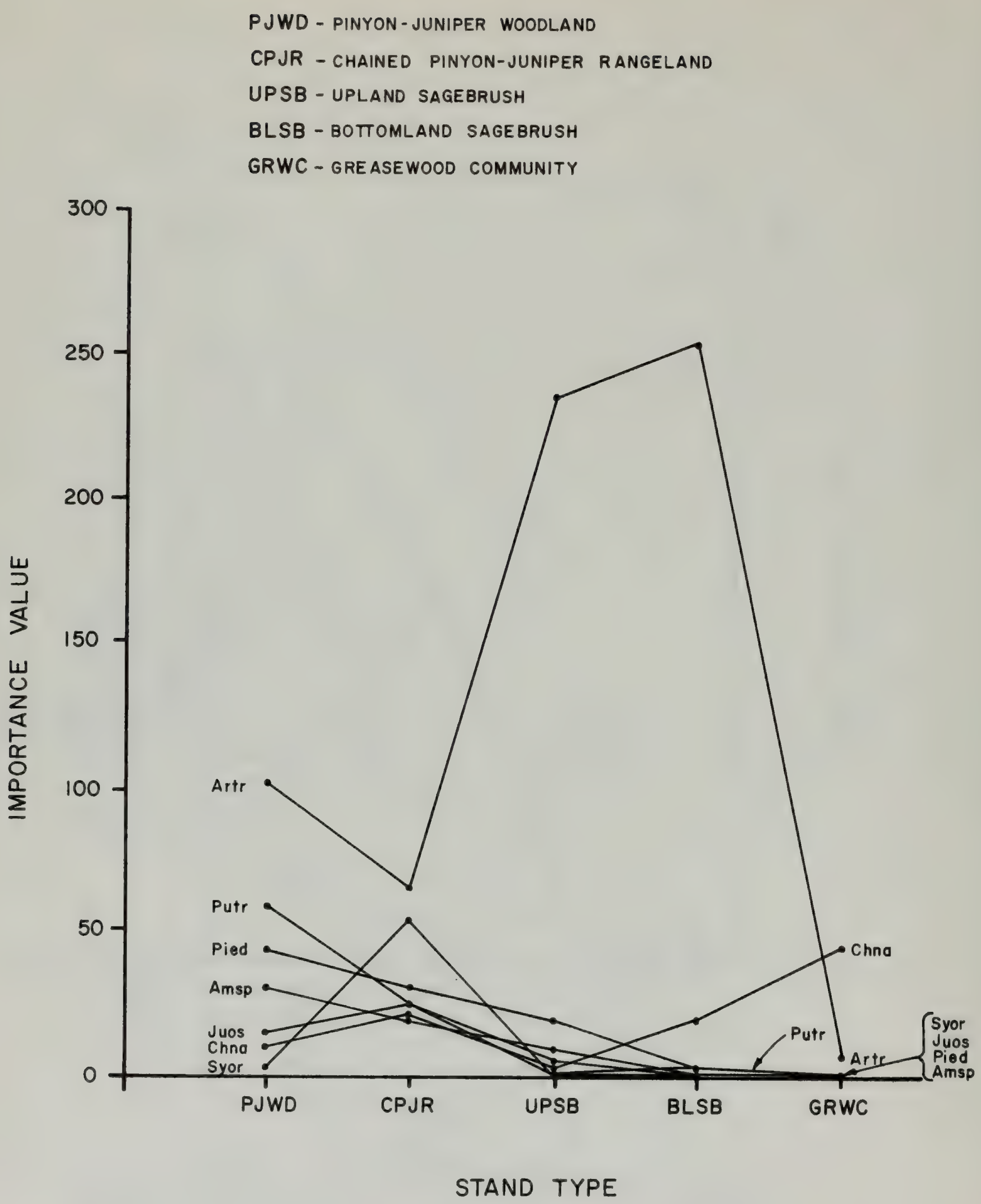


Figure V-80

COMPARISON OF IMPORTANCE VALUE FOR SEVEN IMPORTANT SHRUB SPECIES IN FIVE STAND TYPES IN THE TRACT C-b STUDY AREA.
SEE FIGURE V-52 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

by high salts and trace elements is also shown. Herbaceous species are similarily treated in Figure V-81. This figure indicates that the competitive interactions between herbaceous species are more complex than those between shrub species. Of importance, however, is the decrease in most species as salts and other toxic elements increase in concentration. The preliminary interpretations concerning cheatgrass success in disturbed sites is reenforced in this figure. Sites disturbed by grazing or other disturbance or environmental conditions support increased frequencies of cheatgrass. The importance of western wheatgrass is also substantiated.

PJWD - PINYON-JUNIPER WOODLAND
CPJR - CHAINED PINYON-JUNIPER RANGELAND
UPSB - UPLAND SAGEBRUSH
BLSB - BOTTOMLAND SAGEBRUSH
GRWC - GREASEWOOD COMMUNITY

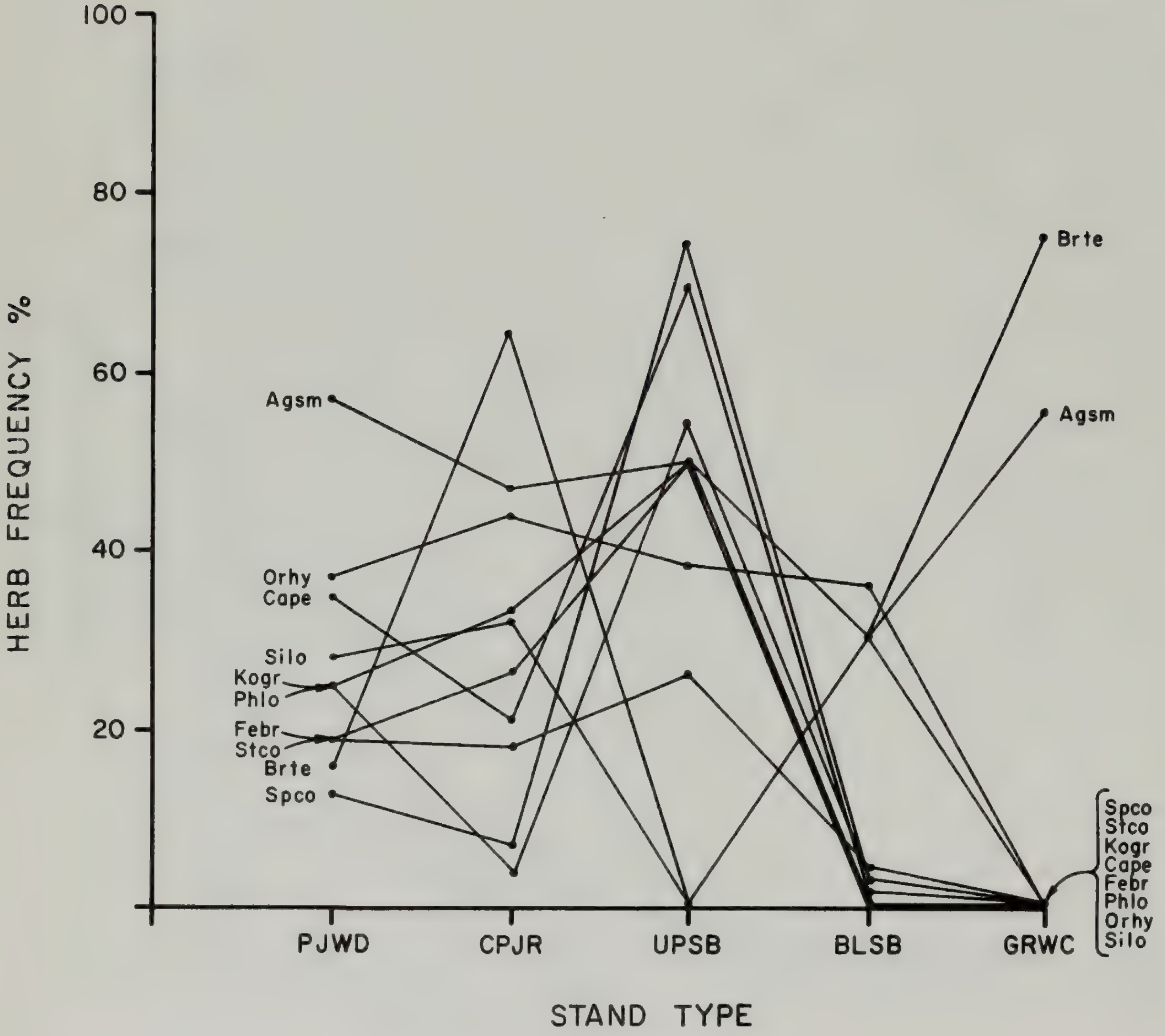


Figure V-81

COMPARISON OF IMPORTANCE VALUE FOR TEN HERBACEOUS SPECIES IN FIVE STAND TYPES IN THE TRACT C-b STUDY AREA. SEE FIGURE V-53 FOR EXPLANATION OF SPECIES ABBREVIATIONS.

H. Historical Climate-Plant Analyses

1. Introduction

Dendrochronology may be defined as the science of measuring time intervals and dating events and environmental changes by reading and dating growth layers of woody plants as demarcated by annual rings. This study in the Tract C-b area is intended to produce a master chronology that dates the growth increments of pinyon pine (Pinus edulis) for the area and to use climatic information and dated growth layers to study variations in past and present climates.

The width of growth rings can serve as natural records of climatic variation when they vary as a function of some limiting environmental factor (Douglas, 1919). In semiarid western Colorado that limiting factor is precipitation (Schulman, 1945). Not all woody plants produce growth-layer sequences that are datable and usable for climatic inference. The shrub species do not preserve a ring-sequence record of sufficient length for dendroclimatology and often the rings are not clearly recognizable. Utah juniper (Juniperus osteosperma), the codominant with pinyon pine (Pinus edulis) on Tract C-b, often produces several growth layers per year making it unsuitable material. Douglas fir (Pseudotsuga menziesii) would be useful material if it were present in the area in larger numbers and in locations demonstrating greater water stress. On the other hand, pinyon pine is present throughout the area and in sites receiving only superficial runoff. Also, it has a sufficiently long tree-ring sequence to make it acceptable for dendrochronologic and dendroclimatic studies.

2. Methodology

Three sampling sites were chosen within the study boundaries of Tract C-b (Figure V-82). Each site was a stand consisting of eight pinyon-pine trees. Four cores were taken from each tree four and one-half feet above the ground (Diameter at Breast Height). The cores were dried in redwood boxes for 10-14 days and then mounted in wooden slats. The cores were prepared for examination by sanding with various grades of sandpaper. Number plots and skeleton plots were constructed for each core using the methods detailed by Glock (1937).

A total of 32 trees were sampled in this study. Twenty-nine trees were used in building the master chronology. Three trees were not included in the master chronology because their growth layers were severely distorted. The growth increments listed in the master chronology (Figure V-83) are indicated by vertical lines (diagnostic growth increments*).

*Diagnostic growth increments are growth layers or rings which are either extremely narrow or extremely wide. The direct response of tree-diameter growth to precipitation allows the use of this diagnostic tool. In years when precipitation is high ring width increases drammatically; similarity ring growth is narrow in years of low precipitation. Since all trees respond roughly equally to precipitation,it is possible to identify and correlate these diagnostic increments between individual trees and to assign a date to them.

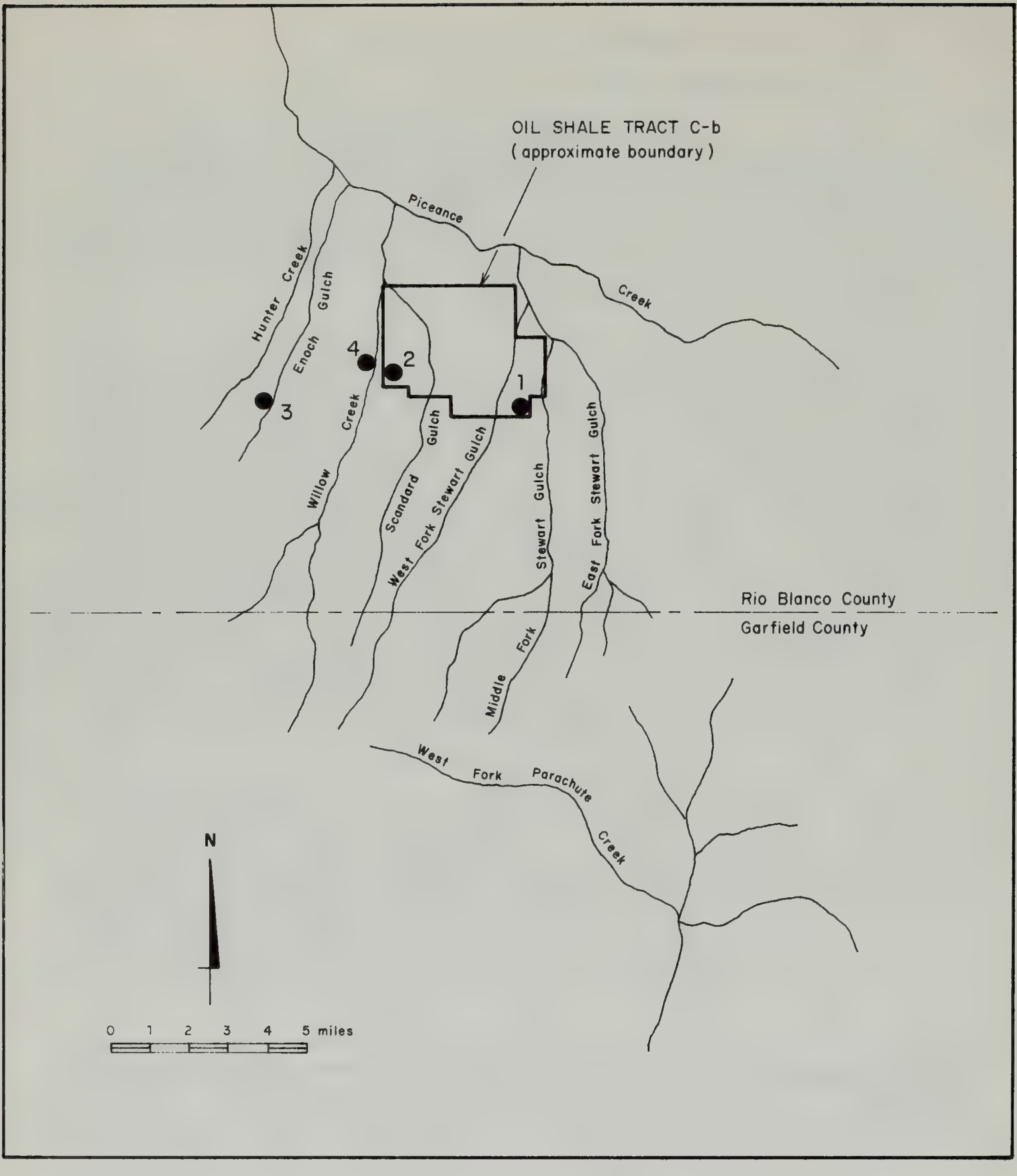


Figure V-82

Stand locations for the Dendrochronologic and Dendroclimatic study.

74-669

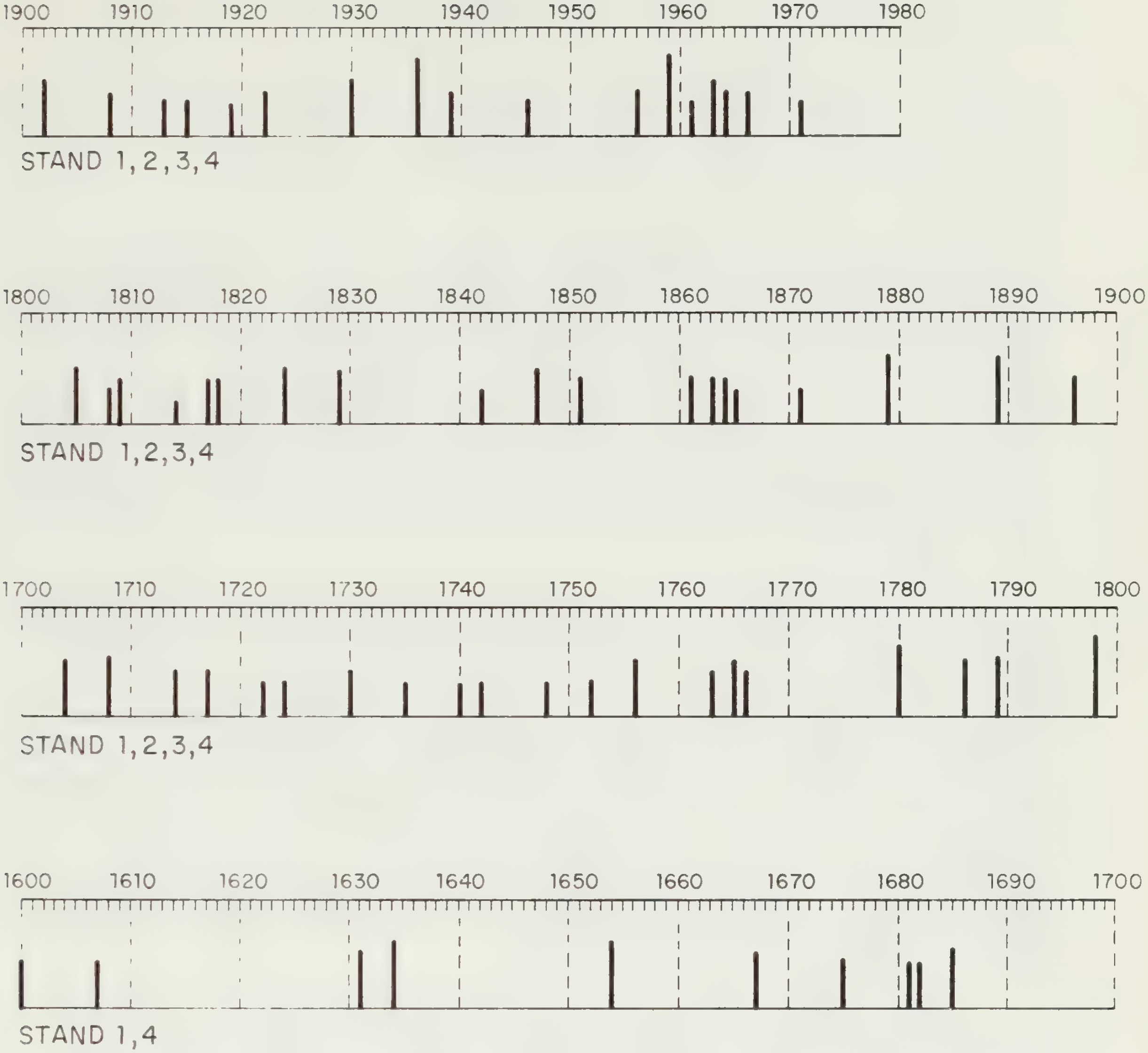


Figure V-83
Master stand chronologies.

These vertical lines represent the relative thinness of that growth increment. The height of the line is inversely proportional to the relative thinness of the growth increment, in relation to its neighbors. Both the height and interval between diagnostic growth layers are important in using a chronology, identifying missing rings and cross-dating.

Following completion of the master chronology, the dated growth increments were measured to 0.01 millimeter with a standardized ocular micrometer. The mean width of each annual increment was calculated for each tree using the four cores taken per tree and plotted graphically against age.

The mean tree-ring measurements for each tree were converted to standardized indices and averaged to obtain a ring-width chronology that is likely to correspond to short-term growth-limiting fluctuations in climate (Fritts, 1971). The standardized indices for each tree were compared with the October-through-June precipitation record from the towns of Meeker and Rifle, Colorado, using Spearman's rank correlation coefficient. It was necessary to correlate the variation in tree growth with precipitation, to establish if the precipitation regime has been a limiting factor in the Tract C-b study area and to establish which trees did or did not reflect this correlation. Twenty-nine trees were used in the correlation.

The dendroclimatic analysis consisted of two phases: modeling and interpretation. Modeling, using both multiple and linear regression, was necessary to predict the past climatic changes knowing only the variations in standardized tree-ring widths. The multiple regression analysis compared standardized tree growth for each year with three independent variables: October-through-June precipitation for each year of growth, October-through-June precipitation for the previous year, and the previous year's standardized growth for each tree. An analysis of variance was performed on each regression and an F-value was calculated. Two trees were eliminated from the final multiple regression analysis: one, because its F-value was below the level of confidence and the second, because its partial regression coefficients differed markedly from the other calculated coefficients.

The standardized, tree-ring indices for the remaining trees were averaged for each year and a multiple regression of mean standardized tree growth for each year was performed. The independent variables were: October-through-June precipitation for each year of growth (x_3), October-through-June precipitation for the previous year (x_2) and the previous year's mean standardized growth for all trees (x_1). An analysis of variance was performed and an F-value was calculated.

The final multiple regression equation, $y_{est} = 0.45x_1 + 0.044x_2 + 0.0011x_3 + 1.03$, was used to calculate the past climatic regimes (y_{est}) using the known precipitation record from Meeker, Colorado, and the tree-ring record extending back to 1437 A.D.

The multiple regression model, though statistically significant, did not

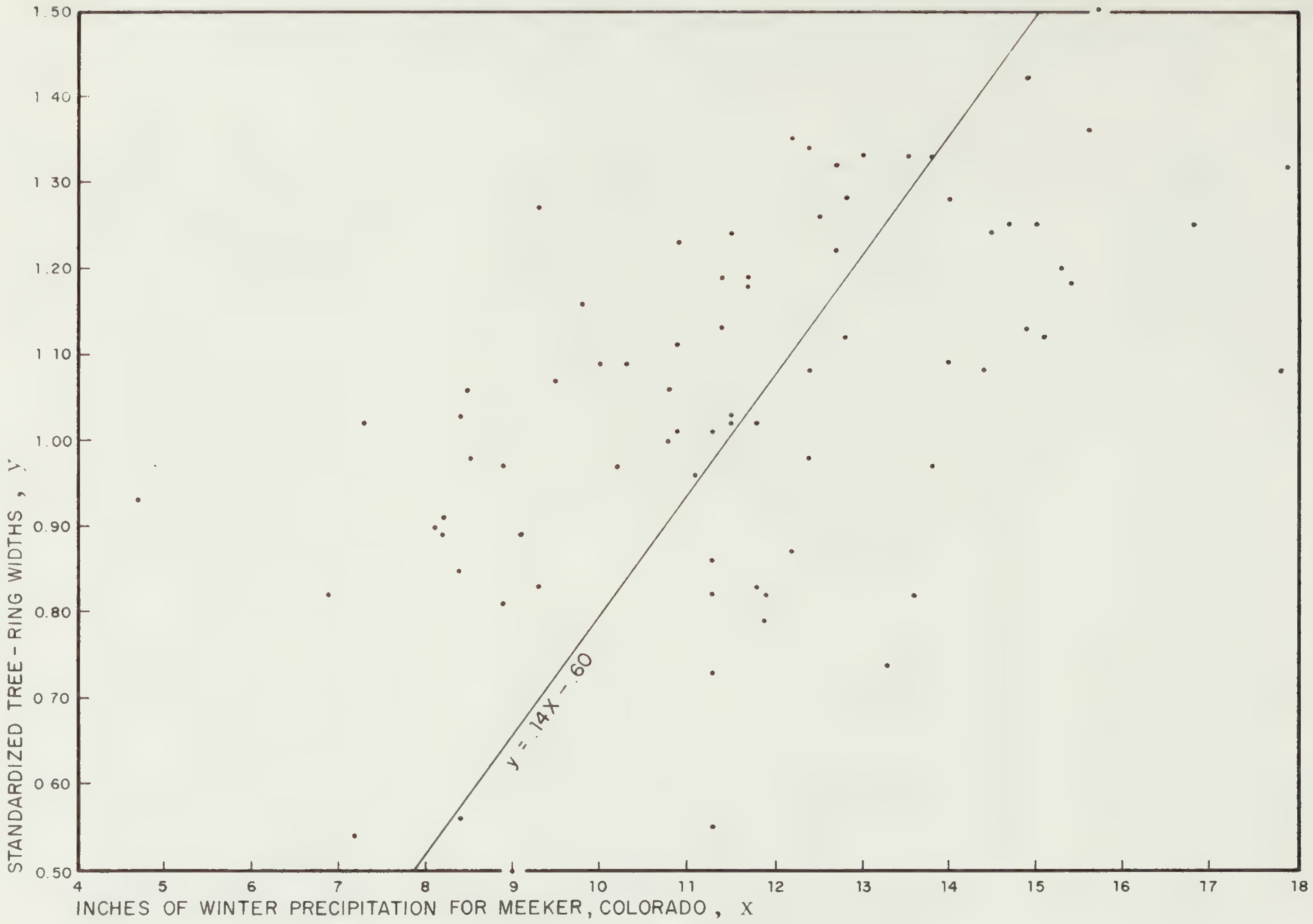


Figure V-84

Scatter diagram and linear regression of ring-widths and winter precipitation.

adequately predict known precipitation values so a linear regression model was constructed, based on 18 trees (11 of the original 29 trees were eliminated from the model; the ages of these trees were less than 250 years and did not meet the requirements of the model), using mean standardized tree growth for each year (y) and October-through-June precipitation for each year of growth (x) (Figure V-84). These values are graphed in Figures V-85 through V-90.

An index of tree age versus tree radius was also calculated, using a simple, linear regression (Figure V-91). The data were taken from twelve radii of chained pinyon pine located on Tract C-b. The sections of wood were prepared by sanding with various grades of sandpaper and each ten-year increment of growth was measured to 0.5 millimeters.

3. Results and Discussion

a. Master Chronology for the Tract C-b Area

A master chronology was constructed for the Tract C-b area (Figure V-83). It dates the growth increments produced from 1437 A.D. through 1974 A.D. The master chronology can be used to date any section of pinyon pine produced in the area. The primary purpose is to date the annual increments of growth used in the dendroclimatological analysis, however, some general climatological inferences can be made from the master chronology. Each diagnostic growth layer in the chronology represents a striking departure from the mean growth of the trees. The frequency of diagnostic growth layers determined on 100 year intervals from 1437 A.D. to 1974 A.D. is 17.5 percent. This implies that the probability of an extreme departure from the mean for any ten year period is 0.0175 or approximately two percent. This frequency roughly describes all the time periods except the 1600's, which have a probability of an extreme departure from the mean of 10 percent (a one percent departure for any ten year period). The lower frequency of diagnostic growth layers in the 1600's indicates a more uniformly changing climate with less dramatic fluctuations in climatic factors as compared to the other time periods.

b. Chaining Practices in the Tract C-b Area

Portions of Tract C-b have been chained or cabled as part of the Bureau of Land Management's program to improve and maintain what are thought to be natural grasslands. The Forest Service believes that by the beginning of the Twentieth Century pinyon pine and juniper were beginning to invade the natural grasslands. Also Barney and Frischknecht (1974) state that pinyon pine and juniper have expanded their ranges in the Intermountain region primarily in the last 100 years. Results from other studies (West, et al.,1975) indicate that 21 percent of sampled pinyon trees, which were not located on rocky hillsides, were less than 100 years old and pinyon trees sampled on the more restricted, rocky sites attained ages in excess of 100 years with a maximum age of 1,000 years.

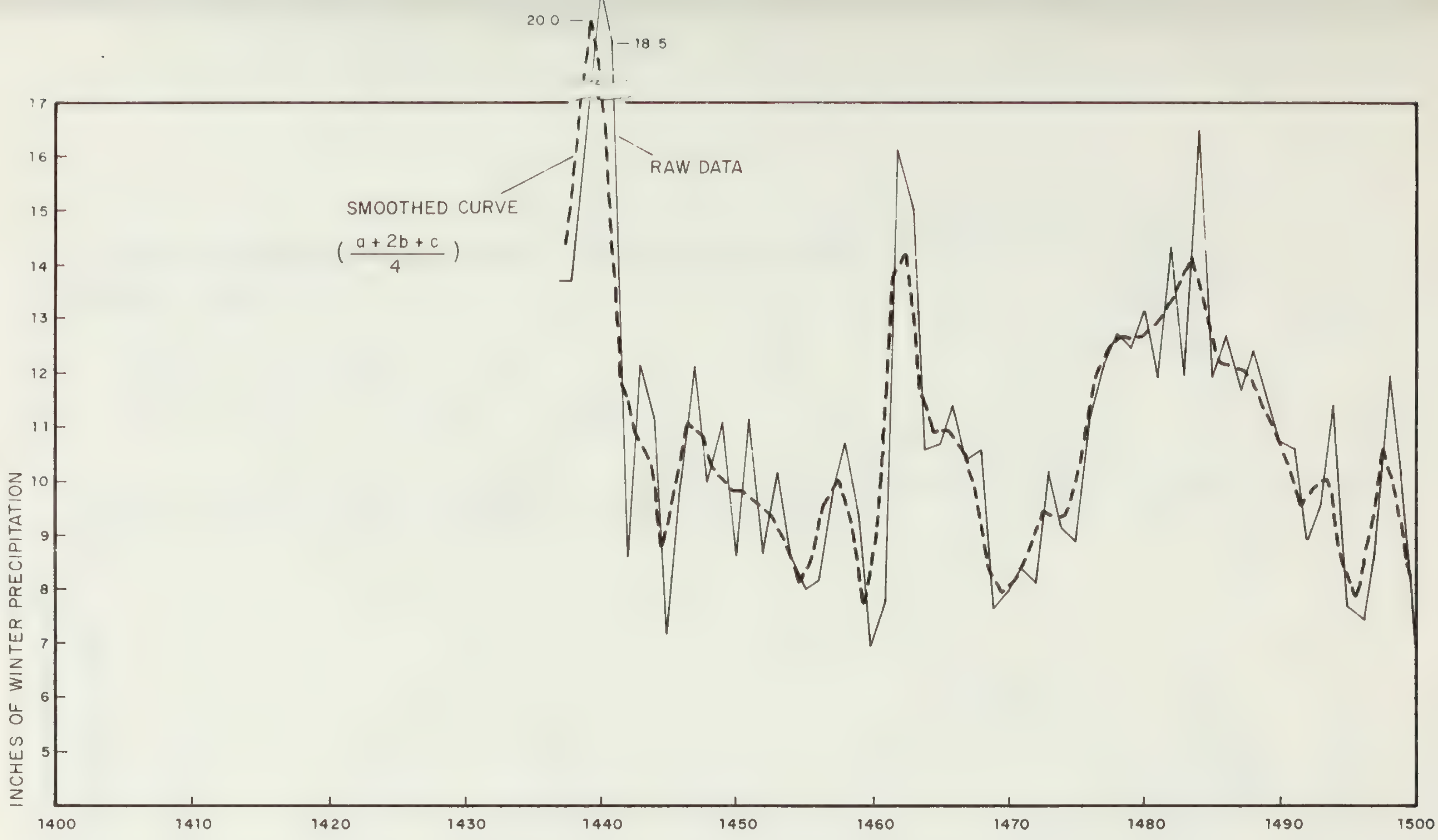


Figure V-85
Predicted winter precipitation regime using the linear regression model, 1400 - 1500.

74-669

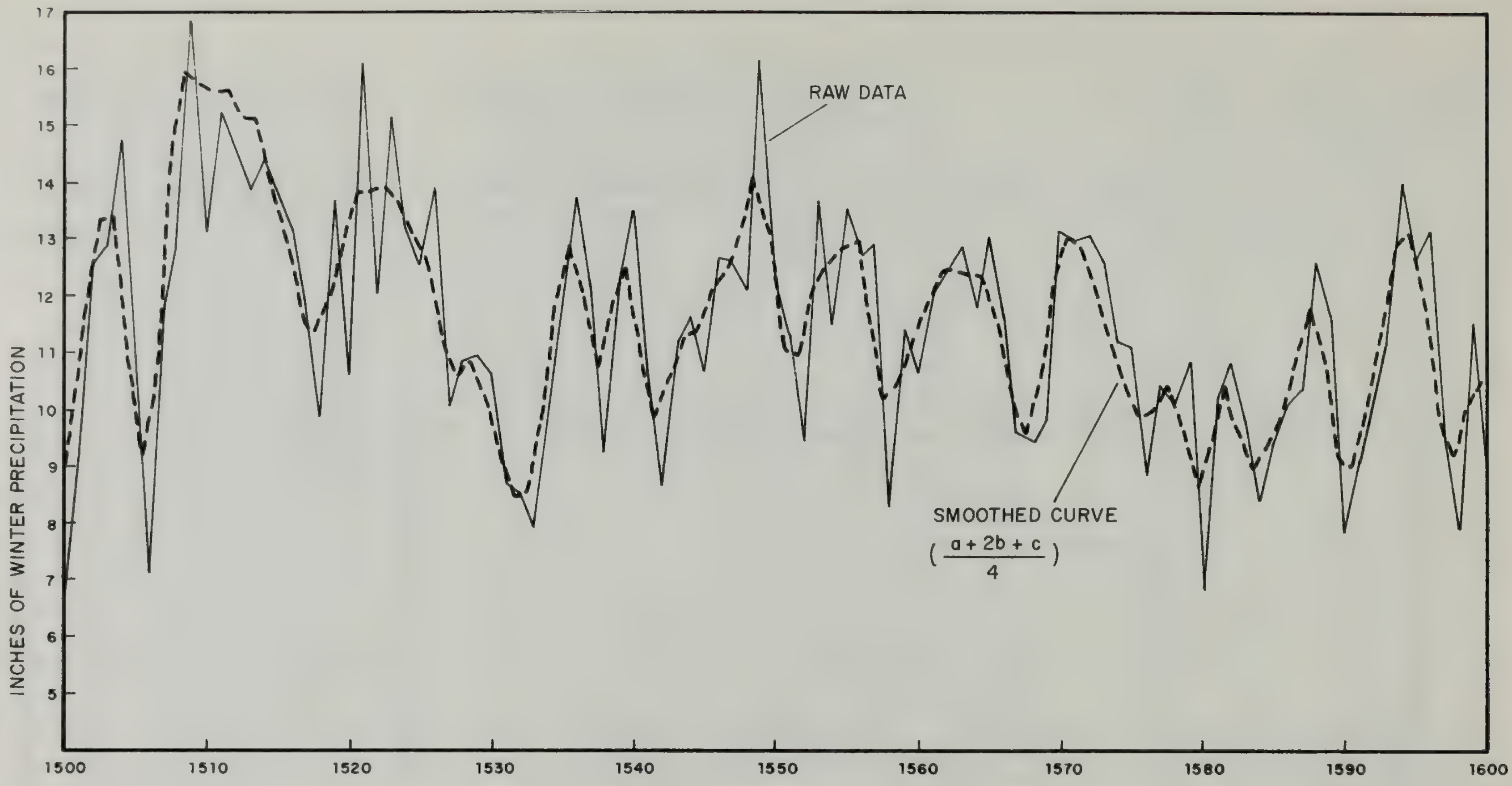


Figure V-86

Predicted winter precipitation regime using the linear regression model, 1500 - 1600.

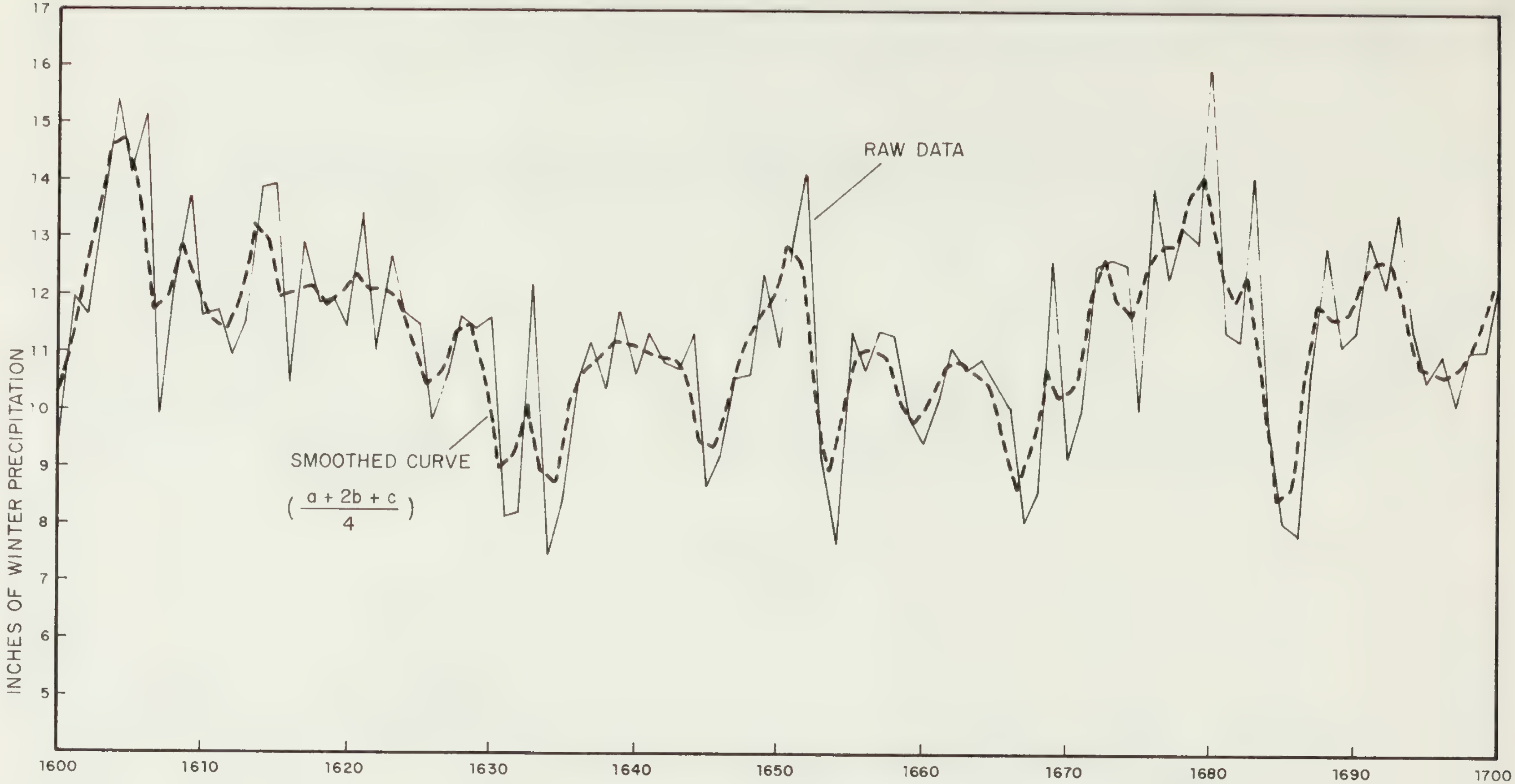


Figure V-87
Predicted winter precipitation regime using the linear regression model, 1600 – 1700.

74-669

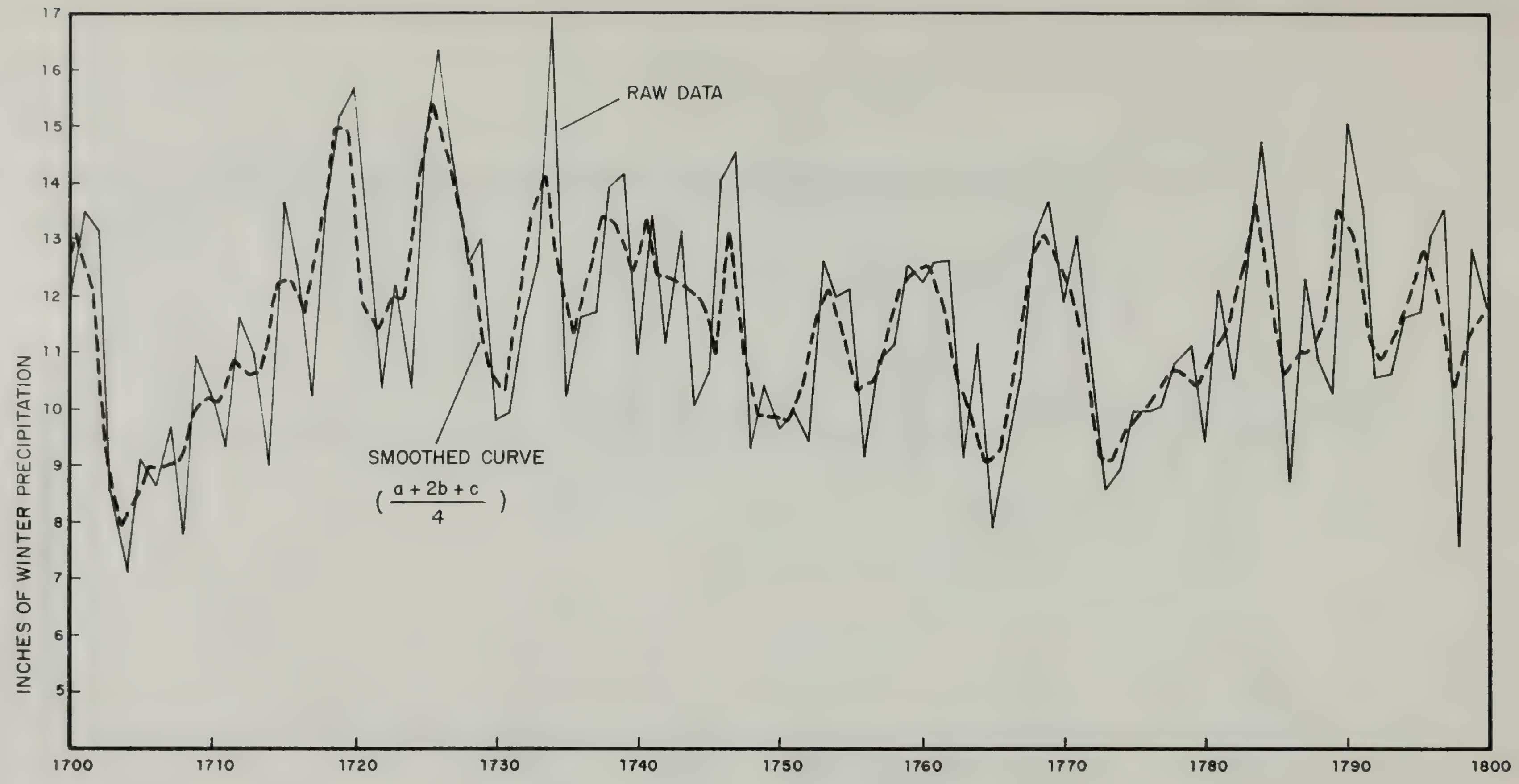


Figure V-88

Predicted winter precipitation regime using the linear regression model, 1700 - 1800.

74-669

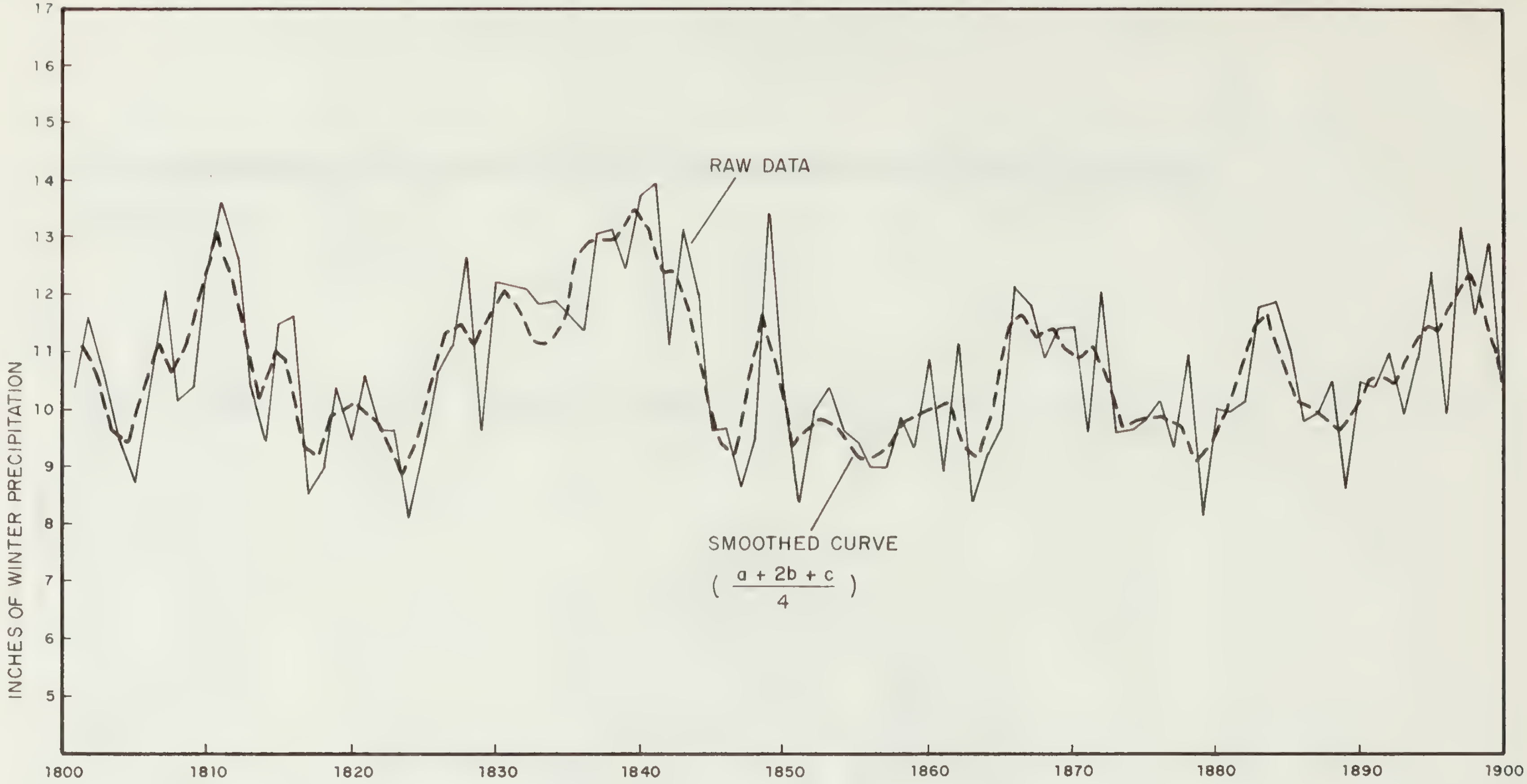


Figure V-89
Predicted winter precipitation regime using the linear regression model, 1800-1900.

74-669

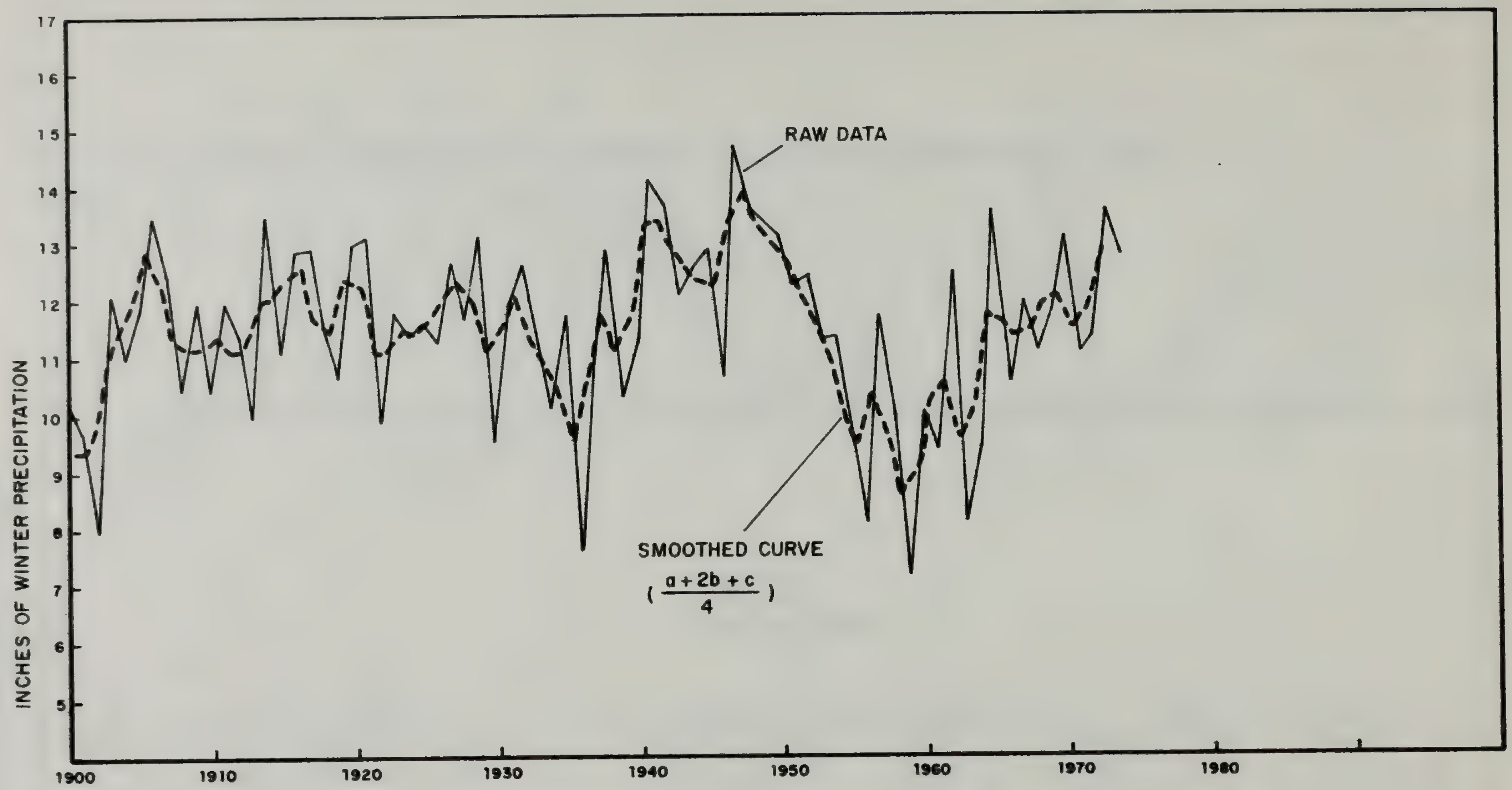


Figure V-90

Predicted winter precipitation regime using the linear regression model, 1900 - 1974.

74-559

On the Tract C-b area, which is probably representative of the Piceance Basin, trees sampled were located in a variety of habitat types. Distribution and age structure stands do not give evidence for increased reproduction of, or invasion by, pinyon pine in the area. The ages of the trees sampled in this study range from 132 years to 537 years at the extremes with 64 percent of the trees older than 200 years. Six sections of pinyon pine collected from the chained areas contained only one individual less than 200 years old and the oldest was 470 years old. The master chronology was used to date these sections. Thus, contrary to the studies mentioned above, the data obtained on Tract C-b do not support the assumption that pinyon pine and juniper are or have been invading the Tract.

c. Growth Rate of Trees in the Tract C-b Area

A linear regression model of tree age versus tree radius was constructed for the pinyon pine (Figure V-91). The model is described by the equation $y_{est} = 0.31x + 28.42$ or $x = 3.23\, y_{est} - 91.68$, where y_{est} represents the tree radius (mm.) and x represents the tree age. The coefficient of determination (r^2) for this model is 0.71. This model can be used as a reference for estimating tree age in the field.

d. Correlation of Ring-Widths and Winter Precipitation in the Tract C-b Area

The 29 trees used in building the master chronology were correlated with the winter precipitation regimes for Meeker and Rifle, Colorado, using Spearman's rank correlation coefficient. All but three trees correlated to the five-percent level of significance and 20 trees were used in the dendroclimatic analysis because their high degree of correlation indicates a higher degree of ring-width variability. The overall correlation of the sample trees with the October-to-June precipitation record demonstrates that winter precipitation is a limiting factor in tree growth on sites with high surficial run-off. These 20 individuals were used in the multiple regression analysis.

e. Fluctuations of Climate in the Tract C-b Area

The climatic interpretation of Figures V-85 to V-90 involves the identification of the true climatic cycles and their relative changes, one with another. The cycles have an average period of eleven years or a multiple thereof. The eleven year cycle is often bi-modal with an average, modal period of six years.

There were five cycles, from 1445 to 1550, with two extremely wet winters occurring in 1462 and 1484. Abnormally dry winters occurred in 1460 and 1550. Schulman (1945) also notes an abnormally dry winter in 1455 which is not seen in C-b data and may be attributed to the initial growth of trees during which time they are relatively insensitive to changes in moisture. Similarly the high value of predicted precipitation in 1440 is attributed to the extremely rapid growth of young trees and the incomplete elimination of growth trend during the analysis.

The 1500's contained ten cycles beginning in 1500 and ending 1598.

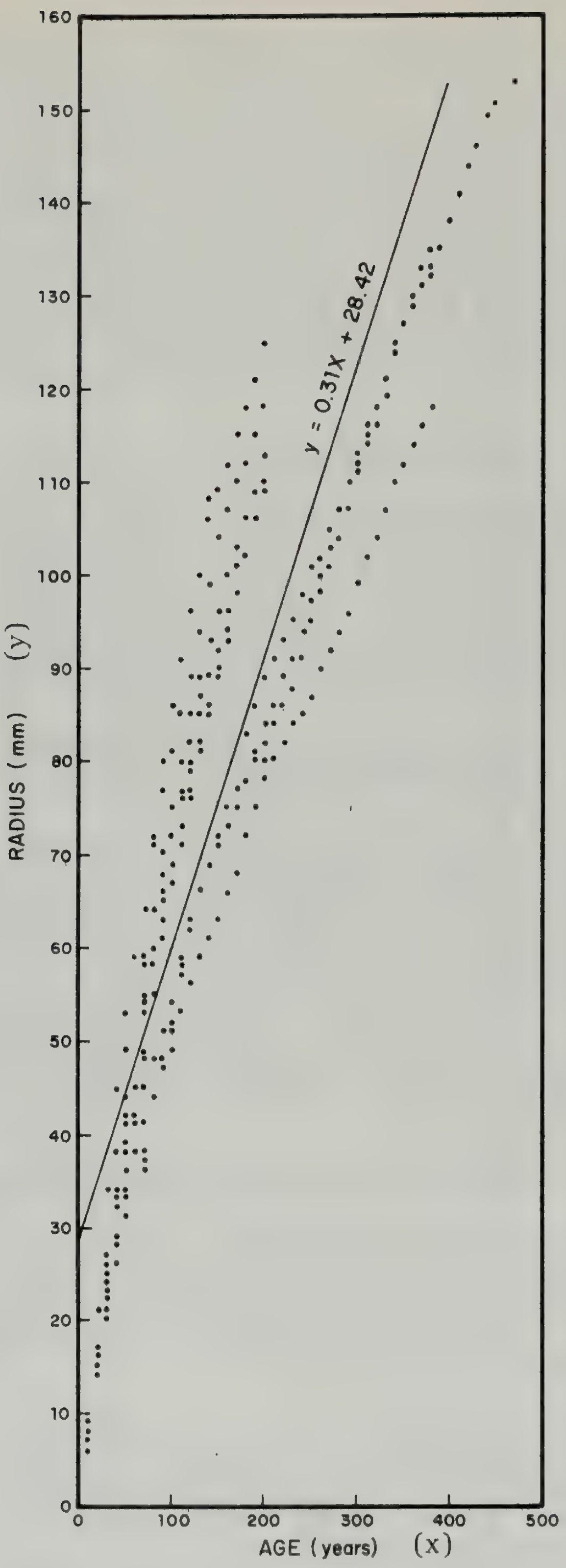


Figure V-91
Scatter diagram and linear regression of tree age and tree radius.

74-669

Abnormally wet winters occurred in 1512, 1523 and 1549. Extremely dry winters occurred in 1506, 1533, 1580, 1590 and 1598. Schulman (1945) notes that the years 1584 and 1585 also had extremely dry winters in the Colorado River Basin. The periods of 1528 to 1534 and 1574 to 1587 were characterized by below-normal winter precipitation.

In the 1600's abnormally wet winters occurred in 1604, 1606, 1652 and 1680. Abnormally dry winters occurred in 1634, 1653, 1685, 1686 and 1704. From 1598 to 1634 the winter precipitation averaged above the mean and is characterized by a 36 year cycle. Order multiple cycles were recorded from 1667 to 1686 and from 1686 to 1704. The climate in the 1600's changed more uniformly and had fewer dramatic fluctuations than did the other time periods.

In the 1700's extremely wet winters occurred in 1720, 1726, 1734 and 1790. Extremely dry winters occurred in 1765 and 1798. The period from 1704 to 1752 was characterized by relatively uniform change demonstrating two multiple cycles in that time span.

In the 1800's abnormally wet winters occurred in 1811, 1841 and 1849; dry winters occurred in 1817, 1824, 1847, 1851, 1863, 1879, 1889 and 1902.

In the 1900's wet winters occurred in 1941, 1942, 1947 and 1957; dry winters occurred in 1919, 1924, 1936, 1959 and 1963. The discrepancy between actual precipitation and predicted precipitation from 1957 to 1961 may be attributed to soil erosion or competition as a direct result of the high amount of winter precipitation. There has been an overall increase in winter precipitation from 1959 to 1974.

From 1437 to 1974 there is no long term trend of generally increasing or generally decreasing winter precipitation or climatic change. The basic cyclic period of eleven years or multiples thereof are continuous throughout the record. Douglas (1936) also shows evidence for the same periodicity of climatic change.

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VI. SOIL SURVEY AND PRODUCTIVITY ASSESSMENT

A. Introduction

A variety of baseline investigations have provided information on the nature and distribution of soils occurring on the Tract and the one-mile surrounding area as follows: 1) a soil survey to classify soils; 2) a physical description of the representative soil types of each soil series including analysis of chemical and physical characteristics of each horizon; 3) a map of soil series and representative soil types; and 4) a correlation of soil series with vegetation units (Figures VI-1 and VI-2). Studies included a productivity assessment, e.g., greenhouse experimentation to determine the amount of plant material supported by different soil types and a correlation of experiments with nutrient analyses.

B. Soil Survey

1. Soil Mapping and Description

The mapping and physical description of the soils on the Tract have been completed by the U. S. Soil Conservation Service (SCS). Since the scope of the SCS project includes the entire Piceance Creek Basin, the preliminary results covering the Tract may be affected by the completion of the basin-wide survey.

The soil classification for soils identified on the Tract is presented in Table VI-1. The soil series and their associated vegetation units are mapped in Figure VI-1. The physical and chemical characteristics used in analyzing the soils of the Tract are summarized in Table VI-2 and their analyses are shown in Table VI-3.

2. Classification of Soils

a. Identification of Soil Taxonomic Units

The soils are classified using the U. S. Department of Agriculture's Soil Classification System (USDA, 1960) adopted for use by the National Cooperative Soil Survey. This is a hierarchical system consisting of six major categories. Each category defines soils at a particular level of abstraction. The highest and broadest category (Soil Order) is useful for studying or comparing soils of very large areas such as countries and continents. The lowest category (Soil Series) defines soils very specifically and is used in detailed surveys.

b. Interpretations of Soil Taxonomic Units With Respect to Soil Moisture

Names of soils at Order, Suborder and Great Group category levels include an identification of the soil moisture regime which refers to the presence of ground water or of water held in the soil at a tension of 15 bars during various periods of the year in the "soil moisture control section." The soil moisture control section is roughly defined

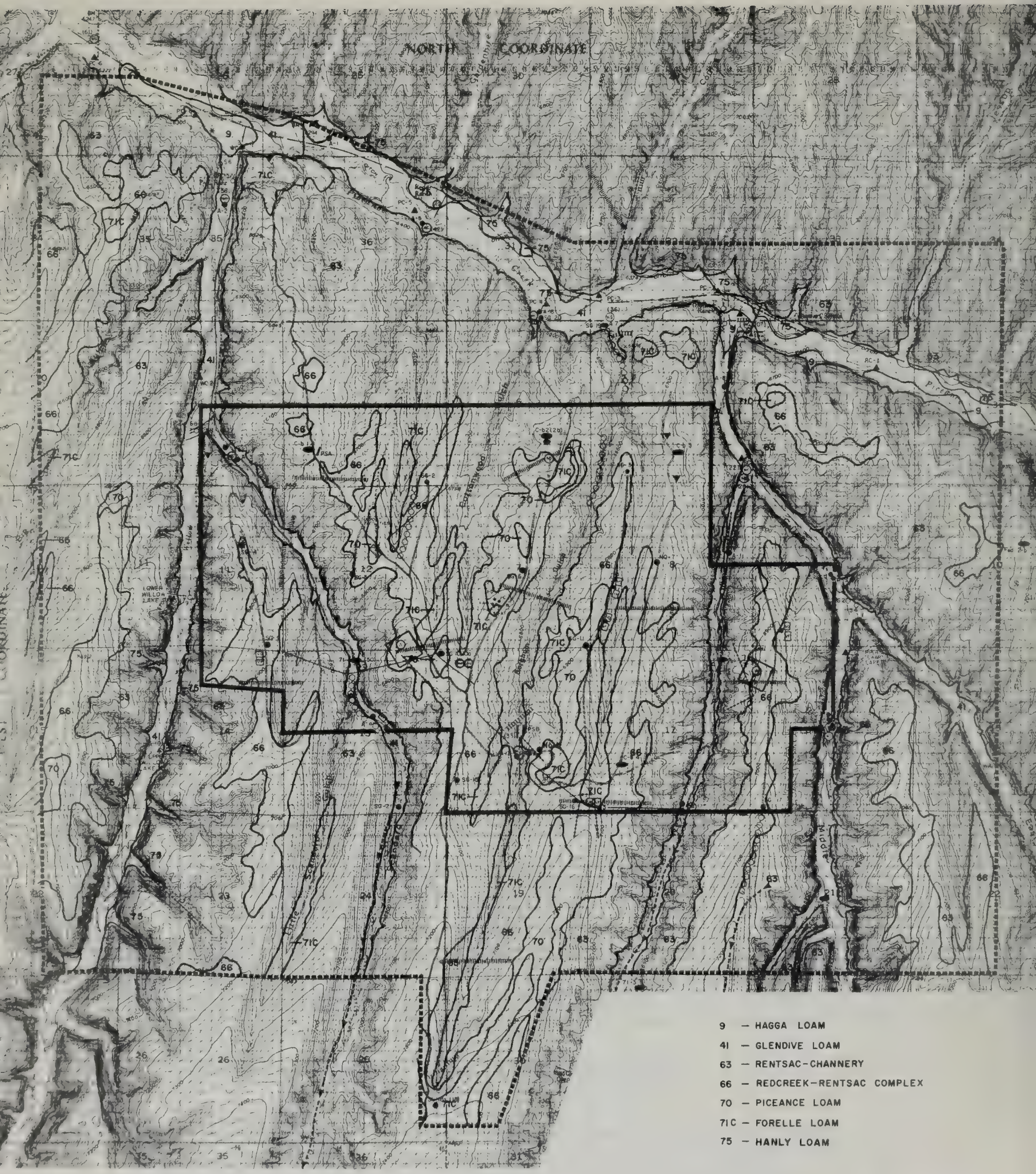

Figure VI-1 SOILS MAP
TRACT C-b

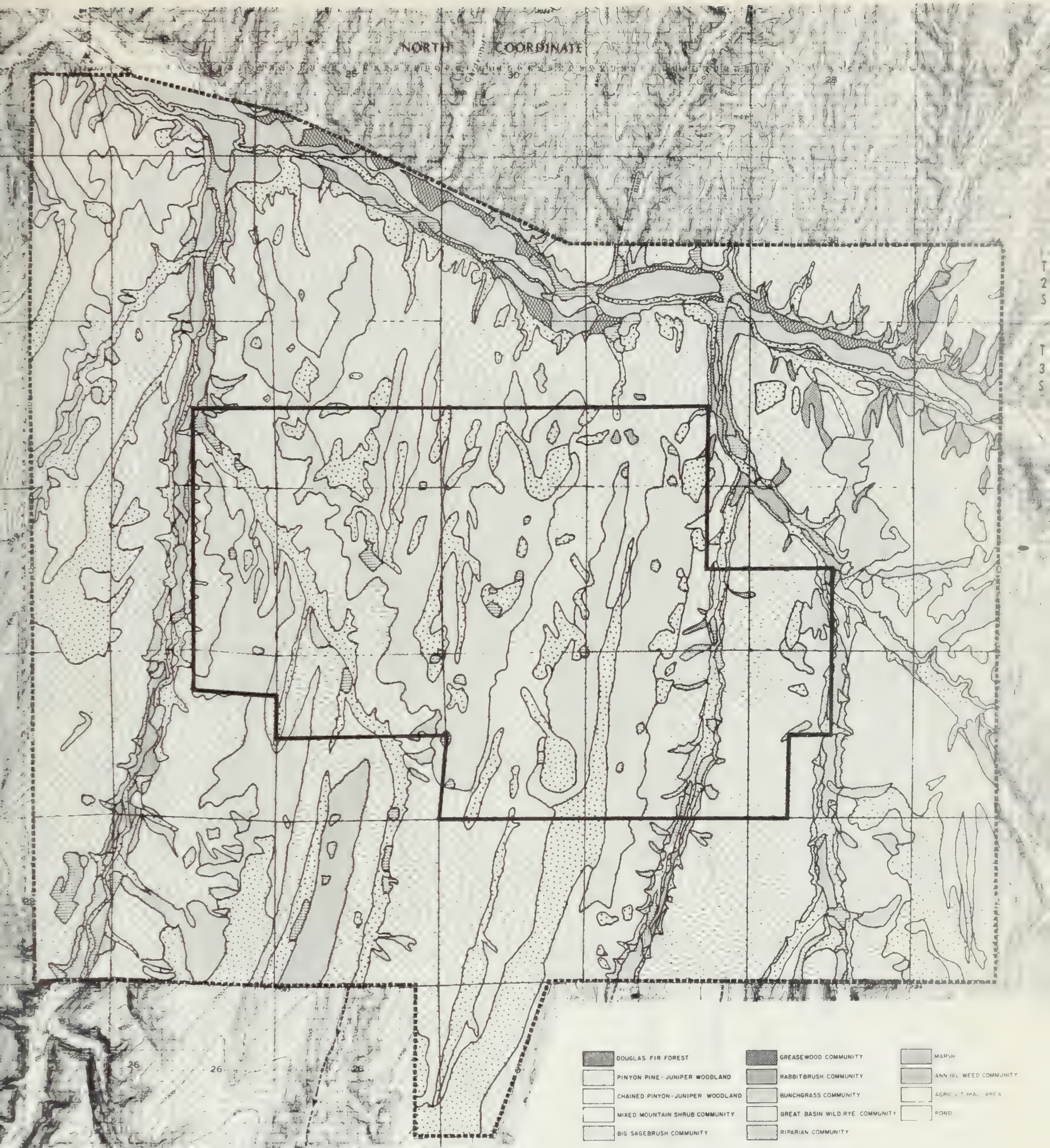

Figure VI-2 VEGETATION MAP

TRACT C-b

Table 11-1 SOILS OF TRACT STUDY AREA

(USDA Soil Classification System, 1960)

ORDER	SUBORDER	GREAT GROUP	SUBGROUP	FAMILY	SERIES
ARIDISOLS	Argid	Haplargids	Borallic	Fine Loamy Mixed	Forelle Loam
	Orthids	Camborthids	Borallic	Fine Loamy Mixed	Piceance Fine Sandy Loam
ENTISOLS	Fluvents	Torrifluvents	Ustic	Coarse Loamy Mixed (Cal.) Frigid	Glendive Fine Sandy Loam
			Ustic	Sandy Mixed Frigid	Hanly Loam
			Typic	Fine Loamy Mixed (Cal.) Frigid	Hagga Loam
	Orthents	Torriorthents	Lithic-Ustic	Loamy Mixed (Cal.) Frigid	Redcreek-Rentsac Complex
			Lithic-Ustic	Loamy Skeletal (Cal.) Frigid	Rentsac Channery

Key to Suffixes and Prefixes: Arid = dry; Arg = Clayey; Hapl = minimum horizon; Bor = cool, high organic; Orth = typical; Camb = altered; Ent = recent; Fluv = deposited by water; Torri = dry, low organic; Ust = dry, summer rains; Typ = typical; Lith = rocky

Other Terminology: Cal. = calcareous; Skeletal = interspersed with rock; Channery = containing fine pieces of sandstone or shale

Table VI-2 SUMMARY OF SOIL CHEMICAL AND PHYSICAL CHARACTERISTICS

1) Agronomic Bulk Sample (determinations made of available fraction)

a) organic matter
b) potassium
c) phosphates
d) nitrate
e) sulfate
f) calcium
g) iron
h) manganese
i) boron
j) zinc
k) copper
l) magnesium
m) ammonia
n) pH
o) electrical conductivity (soluble salts)
p) exchangeable sodium
q) sodium absorption rate
r) cation exchange capacity
s) gypsum
t) lime

2) Trace elements (determinations made of available fraction)

a) molybdenum
b) cobalt
c) selenium
d) arsenic
e) fluoride
f) nickel
g) lead
h) mercury
i) cadmium
j) antimony

3) Other elements and physical parameters

a) sodium (total)
b) chloride (available)
c) textural analysis
d) bulk density
e) permeability
f) field capacity and wilting point (1/3 Bar & 15 Bar)
g) background alpha and beta radioactivity

Laboratory Methods are described in Quarterly Report #4

Table VI-5 SUMMARY OF SOIL ANALYSIS *

	ORTHENTS					ORTHIDS		ARGIDS	FLUVENTS		
SOIL TYPE →	REDCREEK-RENTSAC COMPLEX		RENTSAC CHANNERY	REDCREEK-RENTSAC COMPLEX		PICEANCE LOAM		FORELLE LOAM	GLENDIVE LOAM	HANLY LOAM	HAGGA LOAM
MAP UNIT	66		63	66		70		71c	41	75	9
SAMPLE NO.	6	9	8	3	10	2	5	4	1	12	11
TEXTURE	SN CL LO (Medium)	SN LO (Light)	SN CL LO (Medium)	SI CL LO (Medium)	SN LO (Light)	SN CL LO (Medium)	CL LO (Medium)	CL LO (Medium)	SN LO (Light)	CL LO (Medium)	SI CL LO (Medium)
% ORGANIC	1.6	0.5	2.7	2.1	3.4	1.9	1.4	1.6	1.9	3.6	1.2
% LIME	1.6	2.4	2.3	8.4	5.2	1.5	3.4	8.8	8.1	5.3	1.8
PH-H20	8.2	8.3	7.9	8.3	8.1	8.2	8.3	8.4	8.7	9.5	8.0
NITRATE-NITROGEN ppm	20.1	12.0	50.3	24.6	39.6	23.6	18.6	16.5	30.0	52.0	35.1
AMMONIA-NITROGEN ppm	1.6	0.3	6.8	2.6	6.7	2.2	1.3	1.3	2.8	2.0	2.1
PHOSPHORUS ppm	1.0	1.0	14.0	10.0	6.0	5.0	6.0	3.0	16.0	11.0	1.0
POTASSIUM ppm	51.0	53.0	230.0	85.0	93.0	65.0	50.0	49.0	460.0	190.0	55.0
CALCIUM ppm	3400.0	3700.0	3600.0	2600.0	3900.0	4000.0	3800.0	3600.0	1600.0	2000.0	3300.0
MAGNESIUM ppm	300.0	250.0	420.0	1200.0	160.0	350.0	540.0	560.0	920.0	100.0	610.0
SULFATE-SULFUR ppm	15.0	7.0	2.0	270.0	1.0	31.0	10.0	10.0	990.0	4800.0	19.0
IRON ppm	1.4	2.7	3.9	69.0	4.8	3.4	1.7	1.3	98.0	27.0	3.0
MANGANESE ppm	5.2	0.9	2.6	15.0	2.4	7.2	6.5	4.8	17.0	13.0	6.8
ZINC ppm	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.1
BORON ppm	0.3	0.2	1.0	0.2	0.6	0.6	0.4	0.4	0.7	0.6	0.2
COPPER ppm	0.4	0.2	0.4	2.3	0.9	0.6	0.8	0.7	1.5	1.2	0.8
SODIUM ppm	96.6	98.9	94.3	483.0	103.5	103.5	105.8	181.7	1081.0	3080.0	105.8
ESP	0.7	0.8	0.5	5.1	0.5	0.4	0.2	1.8	10.0	42.7	0.2
SALT-EC	1.2	1.3	1.4	2.7	2.1	1.4	1.8	1.3	8.7	7.5	1.5
OMN	64.0	22.5	108.0	84.0	100.0	76.0	56.0	64.0	85.5	120.0	48.0
EXCHANGEABLE: MEQ/100 gm.											
CA	16.6	18.2	17.5	12.0	18.9	19.5	18.5	17.5	7.5	9.8	15.9
MG	2.4	2.0	3.3	9.7	1.2	2.8	4.3	4.5	6.9	0.7	4.9
NA	0.1	0.2	0.1	1.2	0.1	0.1	0.0	0.9	1.7	8.2	0.0
K	0.1	0.1	0.5	0.1	0.2	0.1	0.1	0/1	1.0	0.4	0.1
TOTAL CEC	19.2	20.5	21.5	23.1	20.9	22.5	23.0	22.6	17.1	19.2	21.0
SATURATED SOIL EXTRACT: MEQ/LITER											
CA	6.3	4.9	7.0	12.2	10.8	7.2	6.8	6.2	10.2	2.9	7.1
MG	1.3	2.3	2.4	3.6	3.1	1.6	2.4	2.1	16.2	1.2	2.8
NA	4.1	5.1	4.3	11.9	6.9	5.4	9.7	5.2	61.5	74.5	5.4
K	0.6	1.0	1.0	1.0	1.4	0.5	0.5	0.7	3.7	0.6	0.6
TOTAL	12.3	13.3	14.8	28.7	22.1	14.7	19.5	14.1	91.6	79.1	15.8
SO_4	0.7	0.5	0.2	13.5	0.1	1.7	0.7	0.5	70.7	63.8	1.2
CL	0.4	0.5	0.9	1.3	1.6	0.6	0.7	0.4	4.4	3.8	0.8
CO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0
HCO3	11.0	12.2	13.5	13.5	20.1	12.2	17.8	13.0	16.1	7.8	13.6
TOTAL	12.1	13.1	14.6	28.3	21.8	14.5	19.2	13.9	91.2	78.7	15.6
S.A.R.	2.1	2.7	2.0	4.2	2.6	2.6	4.5	2.6	16.9	52.3	2.4
% GYPSUM	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
BULK DENSITY	1.59	1.75	1.60	1.48	1.72	1.50	1.54	1.61	1.63	1.41	1.45
PERMEABILITY IN.	0.51	1.62	0.49	0.29	1.57	0.54	0.36	0.35	1.47	0.37	0.30
% FLD CAP 1/3 BAR.	32.2	12.7	27.5	31.2	18.2	31.7	34.8	33.0	18.4	31.1	35.4
% FLD CAP 15 BAR.	17.0	7.5	18.8	23.3	7.2	16.2	20.6	20.6	6.5	18.6	21.0
MOLYBDENUM ppm	0.7	0.5	0.4	1.1	0.4	0.7	0.3	0.3	0.9	0.5	0.4
COBALT ppm	-0.1	-0.1	-0.1	0.2	-0.1	0.1	0.1	-0.1	0.2	-0.1	-0.1
SELENIUM ppm	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	0.03	-0.01	-0.01
ARSENIC ppm	0.07	0.06	0.03	0.04	0.08	0.03	0.03	0.07	0.06	0.04	0.06
FLUORIDE ppm	0.18	0.18	0.21	0.51	0.37	0.21	0.30	0.21	0.36	0.31	0.31
NICKEL ppm	1.1	0.8	0.8	2.6	0.9	1.4	1.2	1.3	1.3	1.1	1.5
LEAD ppm	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
MERCURY ppm	0.004	0.003	0.002	-0.001	0.001	-0.001	0.003	-0.001	-0.001	-0.001	0.005
CADMIUM ppm	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
ANTIMONY ppm	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.0

ANALYSIS

ABBREVIATIONS:

CEC: Cation Exchange Capacity in MG Equiv/100gm.
ESP: Exchangeable Sodium Percentage
SALT-EC: Electrical Conductivity of Saturated Soil Past Extract in MCMHOS/CC
OMN: Estimated Nitrogen Available to Plants in One
SN: Sand or Sandy
SI: Silt or Silty
CL: Clay
LO: Loam or Loamy
S.A.R.: Sodium Adsorption Ratio
-: Indicates Level is Below Reporting Minimum
*: This Table Summarizes the Analyses from the Top Horizon of Each Soil Listed

by depth and particle size, e.g., a depth of 4 inches to 12 inches if the particle-size class is fine-loamy, coarse-silty, fine-silty, or clayey, a depth of 8 to 24 inches if the particle-size class is coarse-loamy, and 12 to 35 inches if the particle-size class is sandy.

The moisture regime helps in understanding the amount of soil development, the nature and distribution of organic matter, base status and the amount of leaching. The greatest significance, however, is related to the potential for growing different plants.

The soil moisture regimes pertinent to the Tract are torric and ustic (USDA, 1960). Torric soils are dry for the greater part of the growing season, are never totally wet and,thus,are deficient in moisture for plant growth. Little or no leaching occurs in this moisture regime and soluble salts will accumulate if there is a source for them. Many of the soils in this moisture regime either have physical properties that keep them dry, such as a crusty surface which retards infiltration, or they are shallow over bedrock. In the study area this soil moisture regime includes the Haplargids, Camborthids, Torrifluvents and Torriorthents (Table VI-1). Weathering of geologic materials exposed in this environment is extremely slow.

In ustic soils overall moisture is limited but there is a surplus of moisture (where precipitation exceeds evapotranspiration) in fall and early winter. Leaching can occur during this period. During the spring and early summer, even though evapotranspiration exceeds precipitation, sufficient moisture is available for plant growth but very little leaching occurs. Summer is a period of moisture deficiency, limiting growth and establishment of plants. Soils in the study area having this soil moisture regime are the Torrifluvents and Torriorthents (Table VI-1).

c. Interpretation of Soil Taxonomic Units With Respect to Soil Temperature

The temperature of a soil is one of its most important properties. Within limits it controls the possibilities for plant growth and soil formation or development by controlling biotic activity and rates of other soil-forming processes.

The soils of the Tract are included in the frigid and mesic soil temperature regimes. A frigid soil has a mean annual temperature lower than 8°C (47°F). Frigid soils of the study area include Torrifluvents, Torriorthents and the Camborthids. The mesic soil temperature regime is characterized by a mean annual temperature of at least 8°C (47°F) but lower than 15°C (59°F) and include the Haplargrids, Camborthids and Torriorthents.

d. General Description of Soil Taxonomic Units

The following is a general description for soils at the Suborder

level found on Tract.

(i) Argids

The argid soils are characterized as having thin, light-colored surface horizons low in organic matter but high in base status. These soils are dry for long periods of time. Because of the low organic matter and generally fine texture (high clay content), some soils in this group take up water slowly and most rainfall runs off. Clays may offer high shrink-swell potential. Water and wind erosion are hazards. Except for a low nitrogen supplying ability, these soils generally have a moderate-to-high fertility status. These soils offer particular problems with respect to plant growth. Subsidence problems may develop through leaching. One argid soil occurs in the study area - a Forelle fine sandy loam (map unit 71C-Figure VI-1, Table VI-1).

(ii) Fluvents

Fluvents are subject to flooding but are not perpetually wet. The parent materials are alluvial sediments and may contain appreciable amounts of organic matter. These soils are highly stratified and their chemical and physical properties vary with depth. Soils in this category could be a valuable source of plant growth medium for covering processed oil shale or coarse geologic materials. Fluvents are an important soil suborder in the Tract study area and include Glendive Loam (41), Hanly Loam (75) and Hagga Loam (9).

(iii) Orthents

Orthent soils are found in areas where little or no soil development is present, e.g., uplands and on erosional surfaces. They have a low organic content and low fertility. Landscapes on which these soils occur are subject to water erosion. Orthents are the most common soils on the Tract. The two series identified as orthents are the Redcreek-Rentsac Complex and Rentsac Loam. These soils underlie pinyon pine-juniper woodlands and chained areas.

(iv) Orthids

The orthids are similar to the argids but without strongly developed subsoil. They are either chronologically younger than the argids, or because of slope, parent material or climatic conditions, or a combination of these, soil development has been retarded. If the latter is the case, this suggests that the soils occur on active erosional surface and that the degree of severity of droughtiness and erosional hazard may be great. These soils have thin, light-colored surface horizons low in organic matter and may have a horizon of salt accumulation. The Piceance (70) series is an orthid occurring in the study area.

e. Classification of Soils on the Tract

Classification of the soils on the Tract is outlined in Table VI-1 and Figure VI-1. All of the soils exhibit common characteristics. They are in areas that have an average annual precipitation of 14-18 inches; the average annual air temperature ranges from 42-45°F. The frost-free period varies from 80 to 105 days, which means the growing season is short. Most of the soils are best suited for livestock grazing and wildlife habitat. Table VI-4 shows the vegetation associations of the soils found on the Tract. Classification of Tract soils and their descriptions follow (USDA, 1975):

(i) Aridisols - Argids - Haplargids

#71C Forelle loam
3 to 8% slopes

A deep, well-drained soil on uplands and terrace slopes at elevations of 6000 to 7200 feet, the Forelle formed in fine-textured aeolian deposits. Typically, the surface layer is a brown loam about four inches thick with a brown, light clay-loam subsoil, 12 inches thick. The sub-stratum is a very pale brown loam extending to more than 60 inches. Lime accumulates in strong lenses in the lower sub-soil and sub-stratum. Permeability is moderate. Effective rooting depth is 60 inches or more. Available water capacity is medium. Surface runoff is slow and erosion hazard slight. This soil is used for dryland farming, livestock grazing and wildlife habitat. It is a good source for fine soil material.

Forelle loam is strongly associated with upland sagebrush-communities and may offer a partial explanation for the occurrence of this vegetation type within some pinyon-juniper woodlands and chained rangelands. This soil differs from the soil commonly underlying the pinyon-juniper type (Redcreek and Rentsac series) in being composed of fine, wind-deposited materials, in having a generally higher nutrient status and differs in maintaining higher field-capacity levels. This soil is somewhat deficient in potassium and phosphorus (probably as a result of a high pH of 8.4) but is high in available nitrogen. All soils in the study area are deficient in zinc.

Forelle loam is also found locally underlying pinyon-juniper woodland and chained rangeland and bunchgrass communities on west-facing slopes.

(ii) Aridisols - Orthids - Camborthids

#70 Piceance fine sandy loam
5 to 15% slopes

This is a moderately deep, well-drained soil on upland slopes and ridges at elevations of 6500 to 7500 feet. Formed in residuum from sandstone and modified with aeolian material, the surface layer develops to a brown, fine-sandy loam about 10 inches thick with a moder-

Table VI-4 SOILS AND VEGETATION ASSOCIATIONS OF THE TRACT C-b STUDY AREA

VEGETATION TYPE	SOILS						
	HAGGA LOAM	GLENDIVE LOAM	HANLY LOAM	PICEANCE LOAM	FORELLE LOAM	RENTSAC CHANNERY	REDCREEK RENTSAC-COMPLEX
PINYON-JUNIPER WOODLAND				X	X	X	X
CHAINED PINYON-JUNIPER RANGELAND				X	X	X	X
BOTTOMLAND SAGEBRUSH		X	X				
UPLAND SAGEBRUSH				X	X	X	X
MIXED MOUNTAIN SHRUBLAND						X	X
DOUGLAS-FIR FOREST						X	
BUNCHGRASS COMMUNITY					X	X	X
GREASEWOOD COMMUNITY			X				
RABBITBRUSH COMMUNITY		X					
GREAT BASIN WILDRYE COMMUNITY		X					
AGRICULTURAL MEADOWS	X	X	X				
RIPARIAN COMMUNITY	X	X					

ate amount of organic material. The subsoil is composed of 12 inches of light yellowish-brown loam over a substratum of very pale brown, very channery sandy loam about 15 inches thick. Lime accumulates in the lower subsoil and substratum. Permeability is moderate. Effective rooting depth is 20 to 40 inches. Available water capacity is moderate. Surface runoff is slow to medium and erosion hazard slight to moderate. It is a fair to poor source for topsoil because of the depth to rock.

Although it has minimal correspondence with the occurrence of pinyon-juniper woodlands and chained rangelands, the vegetative association of the Piceance Loam is similar to that of the Forelle loam, e.g., upland sagebrush. Vegetation associated with this soil is used for livestock grazing and wildlife habitat. This soil is high in nitrates and low in potassium and phosphorus (pH 8.3).

(iii) Entisol - Fluvents - Torrifluvents

#41 Glendive fine sandy loam
2 to 15% slopes

This is a deep, well-drained soil found on valley bottoms over a wide range of elevations (5900 to 7600 feet). Formed in mixed alluvial materials, the surface layer is a pale brown, fine-sandy loam about 12 inches thick containing some organic material. The sub-stratum consists of stratified loams, sandy loams and loamy sands to a depth of more than 60 inches with a similar effective rooting depth. Available water capacity is moderate. With a moderate permeability, surface runoff is slow and erosion hazard slight.

Glendive fine sandy loam predominatly underlies bottomland sagebrush communities and agricultural meadowlands. Table VI-4 indicates other, minimal associations of this soil series. This soil is used for irrigated pasture, livestock grazing and wildlife habitat.

The chemistry is complex and the nutrient level high. The deleterious nature of the sodium sulfate and the total salt concentrations may be counteracted by substantially high nitrate levels. This soil is high in potassium and phosphorus; the effects of high pH (8.7) are apparently counteracted by high sulfate levels.

#75 Hanly channery loamy fine sand
2 to 9% slopes

This is a very deep, somewhat exclusively-drained soil on alluvial fans and cones and on narrow stream bottoms at elevations between 6000 and 6500 feet. Parent material is sandstone or mixed sandstone and shale. Typically the surface layer is pale brown, channery, loamy, fine sand about 6 inches thick with a low organic content. The next layers consist of 37 inches of light, yellowish-brown, channery sand overlying 37 and 60 inches of pale brown and light, yellowish-brown, channery sand,

very channery sand and channery,loamy,fine sand. The soil is highly calcareous. Effective rooting depth is 60 inches or more. Available water holding capacity is low. Permeability is high; surface runoff is slow and erosion hazard is medium.

Vegetation associated with the Hanly soil include bottomland sagebrush, greasewood stands and agricultural meadows which have fair potential for cottontail and deer. They use the grasses, forbs and brush on these soils and obtain their shelter primarily from the brush. This soil is dry and shows high values for nitrogen, potassium and phosphorus but has excessive concentrations of both sodium and sulfate.

#9 Hagga loam
0 to 5% slopes

This is a very deep, poorly-drained soil on flood plains at elevations of 6000 to 6700 feet. It is formed in calcareous alluvium from mixed sandstone and shale sources. The surface layer is loam, about 25 inches thick and except for dark lenses, is light gray. This is underlain by light gray clay loam. Rust-colored iron mottles are common throughout the soil. Permeability is moderate to low. Effective rooting depth is 60 inches or more. Available water holding capacity is high. Organic matter content in the surface layer is medium. Surface runoff is very slow with some ponding. Erosion hazard is slight.

This soil is used for native and seeded grass hay. Limited acreage is seeded to small grain for hay. Yields of the more desirable grasses and small grains are medium. In the fall local ducks utilize the grasses on Hagga soils finding most of the seeds in poorly drained areas too wet to mow. In evenings deer concentrate on Hagga soil for the water associated with it.

This soil, as most of those on or near the Tract, has a high pH value which results in low available phosphorus; nitrate levels are high.

(iv) Entisols - Orthents - Torriorthents

#66 Redcreek-Rentsac complex
50 to 30% slopes

These moderate-to-steep sloping soils are formed in residuum on foothill slopes and ridges at elevations of 6000 to 7600 feet. The Redcreek soil makes up about 60% of the mapping unit #66 and the Rentsac soil makes up about 30%. The Redcreek soil is a shallow, well-drained soil formed in residuum from massive, rapidly weathering sandstone. Typically, the surface layer is a pale brown, sandy loam about 6 inches thick. The substratum, a fine channery, sandy loam about 12 inches thick, rests on massive sandstone. Permeability is moderate to high. The effective rooting depth is 10 to 20 inches and the available water capacity is low. Surface runoff is slow and erosion

hazard is slight. The Rentsac soil is a shallow, well-drained soil that formed in residuum from highly fractured, hard sandstone. Typically, the surface layer is a pale brown, very channery, sandy loam about seven inches thick and rests on hard fractured sandstone. Permeability is high. Effective rooting depth is 10 to 20 inches and available water capacity is low. Surface runoff is slow and erosion hazards slight. The thin soil layers makes this unsuited for use as topsoil.

The Redcreek series is a dry, shallow soil low in fertility. Potassium and phosphorus are low but nitrates are adequate. This soil is commonly associated with pinyon-juniper woodland and chained rangeland but also underlies bunchgrass communities, mixed mountain brush communities and upland sagebrush. Bunchgrass and upland sagebrush communities associated with this, and the following #63 Rentsac series, are frequently on burned sites. These soils are used for limited livestock grazing and for wildlife habitat.

#63 Rentsac very channery, fine sandy loam
5 to 50% slopes

This is a shallow, well-drained soil on foothills and ridge tops at elevations of 6000 to 7600 feet. It is formed in residuum on sandstone that is usually horizontally fractured. The Rentsac soil comprises about 70% of the map unit #63. The surface layer is a pale brown, very channery,sand loam about 4 inches thick. The underlying layer is a pale brown,very channery, sandy loam about 7 inches thick. The substratum is a pale brown,very flaggy,sandy loam about 7 inches thick and overlies fractured hard sandstone. Permeability is high. Effective rooting depth is less than 20 inches. Organic matter content in the surface layer is medium. Available water capacity is low. Surface runoff is medium and erosion hazard is slight-to-moderate. As a source material, such as topsoil, Rentsac is poor because of its thin layering, inclusion of small stones and problems of area reclamation.

The Rentsac channery supports plant communities similar to the Redcreek series, but with the addition of Douglas-fir, and it is not as strongly associated with upland sagebrush. This soil is used for livestock grazing and recreation. It is shallow and dry and has low fertility.

f. Additional Information on Soils

The Soil Survey for the Tract study area categorizes soils according to soil series and the representative soil type in each series is identified. Each soil type has been described in detail by soil horizon. These detailed descriptions are available in quarterly data reports.

C. Soil Chemical and Physical Analysis

The chemical and physical characteristics and parameters used to

analyze soils are shown in Table VI-2 and Table VI-3.

Texture. Soil texture is evaluated as light, medium or heavy. Light soils are those in which the association of fine particles is loose, resulting in good aeration, adequate water movement and suitable soil-root interfacing which increases cation-exchange. Light soils, however, are subject to erosion. A heavy soil restricts the movement of air and water and may decrease cation-exchange. Heavy soils tend to be acidic; light soils are more basic (Brady, 1974).

Organic Matter. The presence of organic matter increases the ability of the soil to retain moisture and provides, to some degree, direct nutrition to plants. The amounts of available nutrition in organic matter, however, are not great. Not all organic material is beneficial. Some toxic organic substances may be present and have deleterious effects in soils that are not well-drained (i.e., soils with heavy texture).

Lime. Lime decreases acidity and improves the texture of the soil. At very high levels, however, lime concentrations may interfere with calcium and boron metabolism and decrease the availability of phosphorus to plants.

pH. The availability of certain elements to plants is directly related to pH. At high pH levels, phosphorus availability is reduced. The pH has similar effects on boron and other trace elements such as iron, zinc and manganese. Very high pH values decrease magnesium and calcium availability. Bacteria and actinomycetes function best at pH values between 6.0 and 7.0, but are not seriously impeded at excessive pH. Fungi do not respond directly to pH values. Nitrate availability correlates directly with micro-organism activity.

Cation-exchange Capacity. Exchangeable soil constituents - cations (such as hydrogen, calcium, potassium and sodium) are necessary for plant growth. Cation-exchange occurs between the plant root and clay fraction of the soil. Cation-exchange capacity relates fairly directly to soil fertility.

Exchangeable Sodium Percentage. Sodium is considered a secondary or micro-nutrient element. In small amounts it is known to increase yields by replacing the action of potassium. In large concentrations, however, sodium is toxic to plants, causing cell plasmolysis (shrinking of protoplasm by dehydration).

Electrical Conductivity of Saturated Soil. Electrical conductivity is a measure of the amount of soluble salts in the soil. When excessive, soluble salts may cause plant toxicity.

Estimated Nitrogen Available to Plants One Year After Decomposition of Organic Matter. This is a projected estimate of nitrogen availability (See Nitrogen).

Selenium. This trace element appears to stimulate growth in some species but is toxic at high levels.

Fluoride. This element acts as a respiratory inhibitor at high concentrations.

Calcium. Calcium is one of the essential plant nutrients. It is vital for the nitrification process. Calcium is also necessary for bud development. High calcium concentrations may interfere with boron metabolism (See Boron).

Magnesium. Magnesium is another of the essential plant nutrients. Magnesium is necessary to the synthesis of chlorophyll.

Potassium. Potassium is an essential nutrient which increases plant vigor and resistance to disease. Potassium also counteracts the effects of too much nitrogen (See Nitrogen). This element aids in the synthesis of starch and the movement of sugar through the plant.

Sodium. (See Exchangeable Sodium Percentage)

Zinc, Iron, Manganese, Copper and Boron. Small amounts of these elements are essential to plants. Although necessary to the overall nutrient regime, all can become toxic to plant growth at high levels. Iron, at high concentrations, interferes with phosphate availability. Manganese also inhibits phosphorus availability, especially in acidic soils.

Phosphorus. Phosphorus is another of the essential major nutrient elements. Phosphorus is doubly important because it influences the absorption of other nutrients by plants. This element is also important to cell division, to the conversion of starch to sugar and to the flowering process.

Sulfur (Sulfate). Sulfur as sulfate is an essential major nutrient element and protein constituent. It is also important in molecules which are involved in cellular respiration.

Nitrogen (Nitrate). Nitrogen as nitrate is essential to plants in the formation of organic components such as proteins, chlorophyll and coenzymes. Nitrogen governs the utilization by plants of such elements as potassium and phosphorus. In high concentrations nitrogen has detrimental effects on plants, such as decreased resistance to disease, retardation of flowering and poor root development. These effects, however, do not occur equally in all plants.

Ammonium Nitrate. This compound is a source of nitrogen both as NH- and NO-.

Chloride. This element is responsible for the stimulation of photosynthesis.

Molybdenum. This trace element is essential to nitrogen-fixation but is toxic in large amounts.

Cobalt. Cobalt is a necessary element in the nutrition of blue-green algae and is required by certain legumes for the fixation of nitrogen.

Arsenic. In high concentrations this element inhibits metabolic processes in living tissue.

Although the interpretations of data on chemical and physical characteristics of soils are incomplete, the basic nutrient status of the surface horizons has been interpreted.

The texture of the soils on the Tract range from light to medium. The four textural categories include: (1) sandy loam, (2) sandy clay loam, (3) clay and (4) silty clay loam. Percent organic matter is generally moderate but is high in several samples. Percent lime in the surface is characteristically high, as is pH (i.e., pH is basic). Cation exchange capacity is moderate. Electrical conductivity of soils is low to average, except in sagebrush bottom lands and in greasewood stands, both of which have excessively high values. Nitrogen estimated to be available from organic matter decomposition in one year's time is generally moderate, except in those cases where organic matter is high (see above). Calcium concentrations are generally high. Magnesium values are moderate for the most part. Potassium is generally deficient, as is zinc. Sodium and manganese concentrations are moderate in most soils. Sodium is excessive in sites supporting greasewood and big sagebrush. Copper is generally moderate, though it was deficient in one sample from a pinyon-juniper site. Sulfur (sulfate) is excessive in three samples (from sagebrush and greasewood sites), deficient in two samples (pinyon-juniper and sage sites) and moderate to low in the remaining samples. Nitrate values were high in most sites and excessive (possibly detrimental) in one site (pinyon-juniper). Ammonia results were identical to those of nitrate. Boron values are moderate in most sites and high in a pinyon-juniper site, though not at a toxic level. Table VI-3 summarizes the physical and chemical characteristics of the several soil types found on the Tract.

The high lime percentages in all soil samples are a possible explanation for low available phosphorus levels, as lime inhibits phosphorus availability (Brady, 1975). Low phosphorus levels may also be the result of pH values in excess of 7.0. The high nitrate values suggest high soil micro-organism concentration, as do high ammonia levels. High to moderate calcium and magnesium values also favorably influence nitrates. Zinc deficiencies may be a result of high pH values, although other trace elements are not affected to the same degree. Available potassium values may be low because of the influence of high lime concentrations on micro-organisms. Lime stimulates micro-organism activity which results in the decrease of available potassium because of its absorption by the microflora.

D. Soil Productivity Assessment

Soil productivity assessment was designed to investigate plant growth characteristics occurring in permanent biological study sites on the Tract.

Soil was obtained from seven sites within the Tract, as shown on Figure VI-3 and Table VI-5. The sites were located at the vegetation plots and at the animal trapping grids. A field analysis of the general

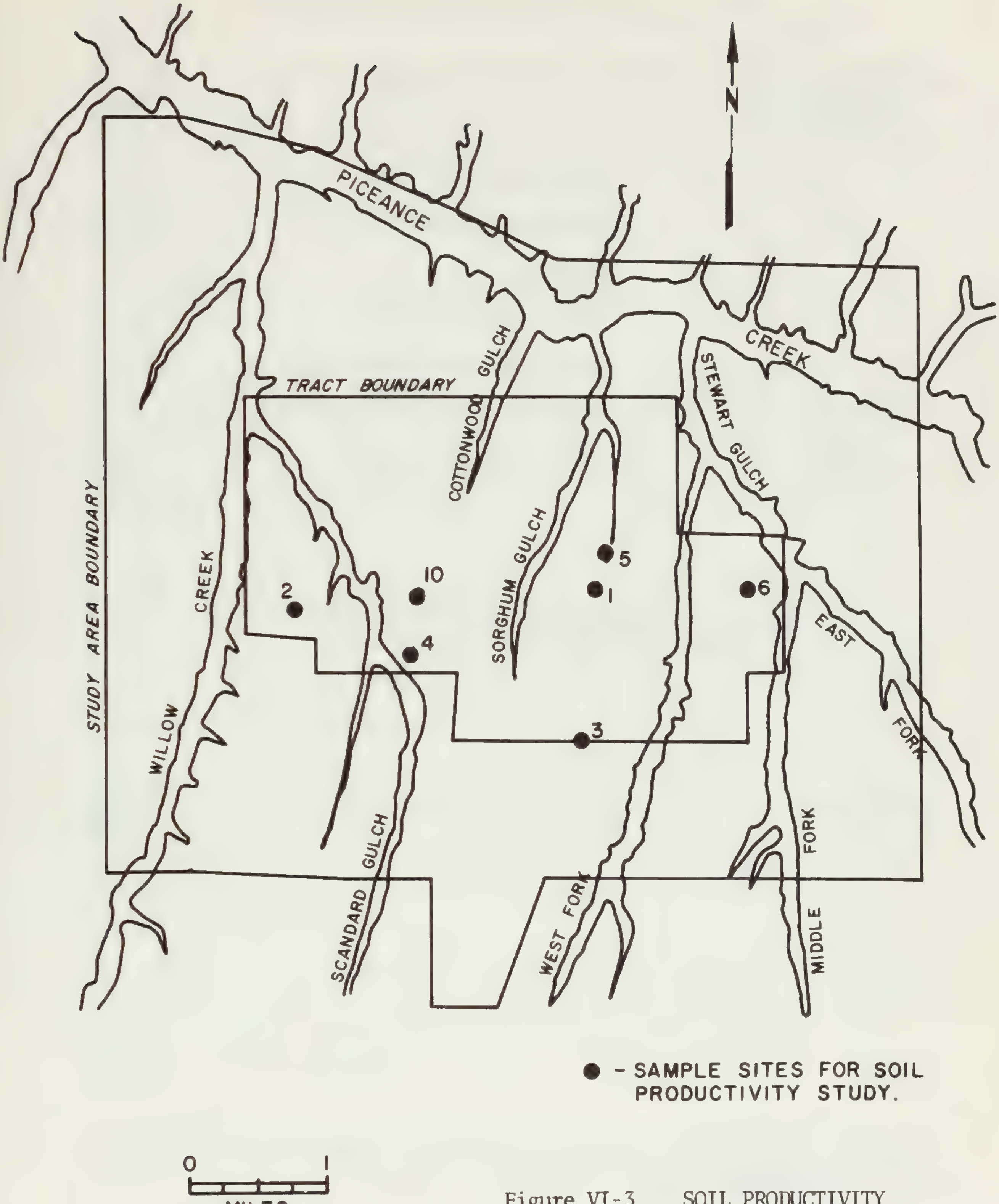

Figure VI-3 SOIL PRODUCTIVITY SAMPLE SITES

Table VI-5 SOIL PRODUCTIVITY TEST SAMPLES

Productivity Assessment Sample Number	Soil Unit Name	Soil Map Symbol
1	Rentsac Channery Fine Sandy Loam	63
2	Redcreek-Rentsac Complex	66
3	Forelle Loam	71C
4	Glendive Fine Sandy Loam	41
5	Rentsac Channery Fine Sandy Loam	63
6	Rentsac Channery Fine Sandy Loam	63
10	Redcreek-Rentsac Complex	66

Table VI-6 GERMINATION RATE COMPARISON FOR SOIL PRODUCTIVITY TEST SAMPLES*

Germination Rate	Calc. x 2	Critical Value x 2	Decision on Null
Hordeum	2.14	14.07	Accept
Avena	3.25	14.07	Accept

* Chi square goodness of fit to test the null hypothesis that no difference in germination rates exists between soil types for hordeum and avena.

soil conditions indicated that these sites all had differing soils.

The soil samples from each site were subsampled and the subsamples placed in each of three nursery flats for a total of 21 experimental flats. Each flat was subdivided into two parts and seeds of the two selected bioassay species were planted in the flat. The species selected were oats (Avena, sativa var. victory) and barley (Hordeum vulgare var. Briggs). Avena was planted in one half of each sample flat and Hordeum in the remaining half. Thus, each flat contained 50 seeds of each species for a total of 150 seeds of each species per soil type.

Control flats were set up with a substrate of vermiculite. The controls were treated with Hoagland's solution to provide a nutrient source.

Germination rates of the two species were measured in each soil type and in the control substrate. Growth parameters were measured on 15 plants of each species in all flats for four weeks following germination. The plants were selected for measurement utilizing a random numbers table. Measurements were made of total stem length, number of nodes, internodal length and leaf length. Growth rate analysis was ultimately conducted on the total plant height only.

At the end of the four-week growth period, the plants were harvested. All plants were removed from the soil the shoot lengths measured, dried and weighed to get an oven-dry weight of biomass accumulated over a four-week period. Subsamples of each soil sample were analyzed. The shoot length and biomass data were treated to graphical and statistical analysis to substantiate the significance of the differences in the observed productivity of the various soils.

The selected species, H. vulgare var. Briggs and A. sativa var. victory, show no difference in germination between soil types (Table VI-6). However, both species showed greatest growth and biomass accumulation in soil types 2 and 10 (Redcreek-Rentsac Complex) with less production in the other soil samples. Production was greater in the vermiculite control, as indicated in Figures VI-4 and VI-5 and Tables VI-7 and VI-8.

Soil sample 1 is significantly more productive in terms of oats and barley than is sample 10, and sample 10 is significantly more productive than samples 1 (Rentsac Channery Fine Sandy Loam), 3 (Forelle Loam), 4 (Glendive Fine Sandy Loam), 5 (Rentsac Channery Fine Sandy Loam) and 6 (Hagga Loam) (Figures VI-4 and VI-5; Tables VI-7 and VI-8).

Samples 1, 3, 4, 5 and 6 are essentially soil samples with low productivity and samples 2, 10 and the control are different samples having significantly higher productivity in terms of shoot length growth. The biomass data tend to be slightly more complex, with the low productivity soils forming three populations. Samples 3, 6 and 4

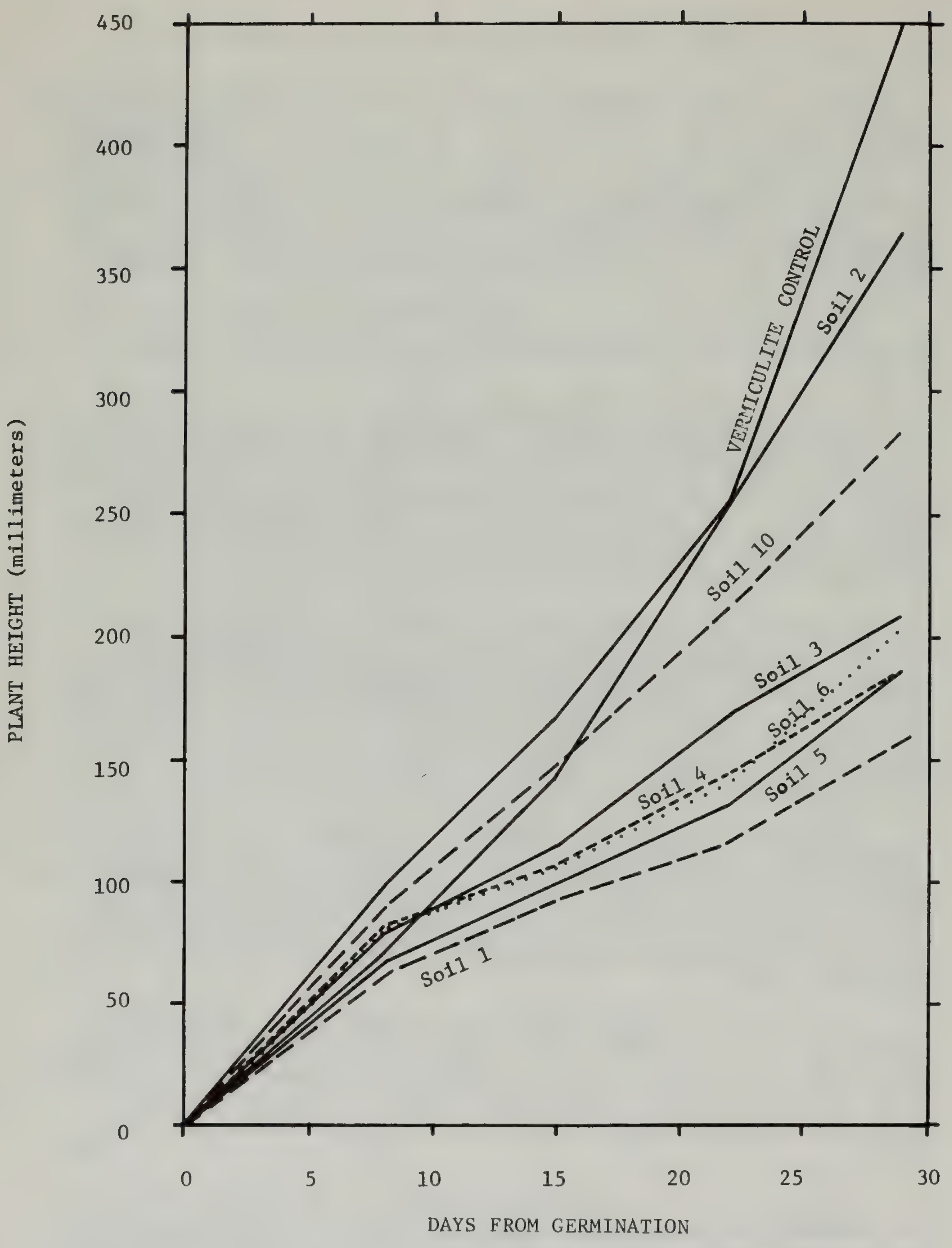

Figure VI-4 GROWTH OF <u>Avena sativa</u> var. Victory

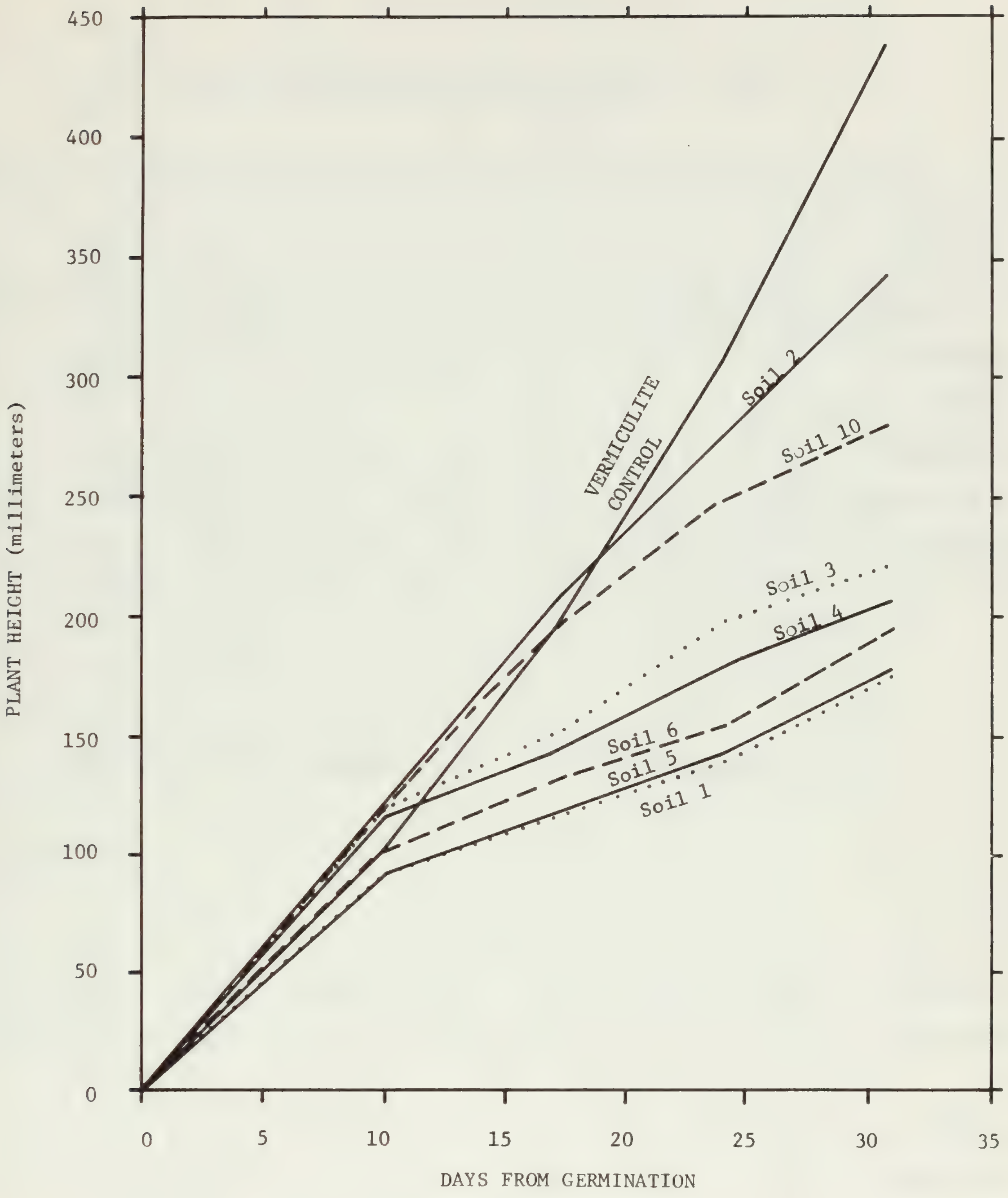

Figure VI-5 GROWTH OF Hordeum vulgare var. Briggs

Table VI-7 SHOOT LENGTH COMPARISON FOR SOIL PRODUCTIVITY TEST SAMPLES

HORDEUM															
Soil Sample	1		5		6		4		3		10		2		C
X Shoot Length	173±13		171±22		193±9		203±18		220±9		277±12		341±29		438±13
Difference	$\tilde{X}_1$	=	$\tilde{X}_5$	=	$\tilde{X}_6$	=	$\tilde{X}_4$	=	$\tilde{X}_3$	=	$\tilde{X}_{10}$	=	$\tilde{X}_2$	=	$\tilde{X}_C$
AVENA															
Soil Sample	1		5		4		6		3		10		2		C
X Shoot Length	152±9		185±21		186±15		201±14		207±15		282±10		363±19		448±24
Difference	$\tilde{X}_1$	=	$\tilde{X}_5$	=	$\tilde{X}_4$	=	$\tilde{X}_6$	=	$\tilde{X}_3$	=	$\tilde{X}_{10}$	=	$\tilde{X}_2$	=	$\tilde{X}_C$

Table VI-8 BIOMASS COMPARISON FOR SOIL PRODUCTIVITY TEST SAMPLES

HORDEUM															
Soil Sample	5		1		6		3		4		10		2		C
X Biomass	.0255		.0267		.0297		.0384		.0387		.0573		.1234		.2184
Difference	$\tilde{X}_5$	≠	$\tilde{X}_1$	≠	$\tilde{X}_6$	≠	$\tilde{X}_3$	≠	$\tilde{X}_4$	≠	$\tilde{X}_{10}$	≠	$\tilde{X}_2$	≠	$\tilde{X}_C$
AVENA															
Soil Sample	1		5		3		6		4		10		2		C
X Biomass	.0221		.0271		.0317		.0322		.0328		.0542		.1110		.1424
Difference	$\tilde{X}_1$	≠	$\tilde{X}_5$	≠	$\tilde{X}_3$	≠	$\tilde{X}_6$	≠	$\tilde{X}_4$	≠	$\tilde{X}_{10}$	≠	$\tilde{X}_2$	≠	$\tilde{X}_C$

are relatively low in productivity compared to 2 and 10, while soil samples 5 and 1 (Rentsac Channery Fine Sandy Loam) are significantly different from each other and lower in productivity than 3, 6 and 4. *Avena* biomass production is lowest in soil sample 1 and *Hordeum* is lowest in sample 5 as indicated in Table VI-9.

No significant correlation was found between the nutrient levels occurring in the soils and the productivity of the bioassay species. However, NO_3 levels in soils 2 and 10 are three to five times higher than NO_3 levels in the other soils (Table VI-10). In addition, phosphorus levels, while low throughout the Tract, are relatively high in samples 2 and 10. Two additional patterns are apparent in the soil analysis data: the SO_4 levels in samples 2 and 10 are two to five times lower than the other sites; and the electrical conductivity test for salts indicates that the salt content of samples 2 and 10 is up to two-times that of the less-productive soils.

No trends were noted in the other soil analysis data. All other parameters analyzed (e.g., cation-exchange capacity and soil water retention) exhibited overlapping variations in magnitude.

The relatively higher salt content and lower sulfur content of soils 2 and 10 are generally considered to be disadvantageous to plant growth. However, these conditions are apparently countered by the higher level of NO_3 and slightly increased level of phosphorus in the more productive soils. The high level of available NO_3 appears to be the most important difference between the Tract soils in the areas around soil sample sites 2 and 10 and those in the other five sites. Since the NH levels are similar at most sites, larger populations of nitrifying bacteria may be present at sample sites 2 and 10, thus making increased NO_3 available for plant growth.

Table VI-9 ANALYSES OF SHOOT LENGTH VS. BIOMASS FOR SOIL PRODUCTIVITY TEST SAMPLES

HORDEUM		Regression Equation	Correlation Coefficient (r)	Regression Critical F	ANOVA Decision	Confidence Limits Of B (slope)
Soil	1	$\hat{y} = .0002X-.0148$	.9269	41.67	Reject	$.0002 \pm .00007$
	2	$\hat{y} = .0006X-.0932$	.7812	68.41	Reject	$.0006 \pm .0001$
	3	$\hat{y} = .0002X-.0221$	.7239	60.00	Reject	$.0002 \pm .00007$
	4	$\hat{y} = .0002X-.0112$	.7692	66.98	Reject	$.0002 \pm .00004$
	5	$\hat{y} = .0002X-.0154$	.9465	550.00	Reject	$.0002 \pm .00002$
	6	$\hat{y} = .0002X-.0218$	.8194	115.00	Reject	$.0002 \pm .00005$
	10	$\hat{y} = .0004X-.0596$	.8842	148.75	Reject	$.0004 \pm .00006$
	C	$\hat{y} = .0004X-.0406$	.3222	5.0232	Reject	$.0004 \pm .0003$

AVENA

Soil	1	$\hat{y} = .0002X-.01$	.7928	87.48	Reject	$.0002 \pm .00004$
	2	$\hat{y} = .0008X-.1969$	.8960	176.04	Reject	$.0008 \pm .00012$
	3	$\hat{y} = .0002X-.0161$	.8407	112.21	Reject	$.0002 \pm .00004$
	4	$\hat{y} = .0002X-.0086$	.8705	143.15	Reject	$.0002 \pm .00002$
	5	$\hat{y} = .0002X-.0132$	.9522	622.73	Reject	$.0002 \pm .000001$
	6	$\hat{y} = .0002X-.0083$	.7437	66.67	Reject	$.0002 \pm .00004$
	10	$\hat{y} = .003X-.0468$	.9054	231.67	Reject	$.0003 \pm .00004$
	C	$\hat{y} = .0005X-.0965$	.5532	19.67	Reject	$.0005 \pm .0002$

Critical Value F (.05) = 4.07

Table VI-10 NUTRIENT ANALYSIS FOR SOIL PRODUCTIVITY TEST SAMPLES

Nutrients (ppm)	Soil Samples 1 (63)	2 (66)	3 (71C)	4 (41)	5 (63)	6 (63)	10 (66)
NO_3-N	5	27	6	10	7	7	38
NH_4-N	28	39	18	23	38	38	46
P	6	26	16	2	7	24	30
K	120	130	250	300	130	220	490
Ca	4900	2900	2600	3400	4200	2600	4100
Mg	200	380	550	230	290	410	340
SO_4-S	17	6	37	10	27	14	5
Fe	5.2	10	7.2	2.6	9.7	29	6.6
Zn	.5	.4	.5	.2	.5	3.6	1.3
Cu	.7	.3	.8	.5	.5	1.3	.7
Mn	1.0	1.9	3.7	.9	1.4	9.6	2.5
B	.5	.8	.8	.9	.5	.6	1.2
Salts $ECx10^3$	.28	.47	.27	.31	.32	.29	.58
Water – Holding Capacity, 15 BAR	11	10	14	10	16	18	17

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VII. EVOLVING CONCEPTUALIZATION OF ECOLOGICAL INTERRELATIONSHIPS ON THE C-b TRACT

The objective of this section is to begin the conceptualization of the ecological interrelationships on the Tract. Successful oil shale development includes consideration of engineering, ecological, economic, social and political components. This section contains a conceptual structure which can evolve as more information is obtained about the biotic complexes within the Tract and man's potential influence on them. Such complex systems contain many components--abiotic (meteorological, edaphic ...), biotic (plants, animals ...) and cultural (economic, sociologic, political ...). The following conceptual categories are treated in this section:

(1) considerations of some of the concepts and terminology that are needed for this evolving framework,

(2) development of an understanding of the spatial, structural units in the area,

(3) illustrations of the initial concepts of organism and system functions,

(4) discussions of some key structure-function interrelationships on the Tract and

(5) preliminary demonstration of these concepts of structure and function and their application to evaluating man's potential impacts in the area.

The approach outlined above provides a means of conceptualizing and integrating both data and techniques from diverse groups of specialists working on the single, real-life, complex problem of understanding a system.

The first-year studies on some parts of the system in Chapters V and VI have been summarized, e.g., biotic communities and soil survey and productivity assessments. Within these chapters there are maps of the soil types and vegetation types on the C-b Tract. Individual animal populations and their dynamics and the plant communities and their dynamics have been discussed in Chapter V.

A. Introduction to a Conceptual Framework for Ecological Decision-Making

Used alone the usual intuitive decision-making practices may be inadequate for developing long-term strategies or specific tactics for maintaining complex physical-biotic-cultural systems in perpetuity. This

approach is inadequate because of the large number of complex interactions between system components. Intuitive planning has a short look-ahead time horizon. In dealing with complex systems a long-term, look-ahead approach may be required to isolate the cause-and-effect relationships and to obtain an understanding.

A potential working solution to these relationships can be accomplished through the development of a conceptual framework using a systems approach. It is possible to develop diagramatic frameworks in which concepts may be ordered in a logical manner. Moreover, such frameworks can be developed eventually which are expressions of the relationships between the biotic and abiotic components of ecological systems and also incorporate important aspects of the social, economic and legal systems involved in the shale oil situation. The conceptual models will be useful tools for analyzing potential impacts of different management decisions.

This approach will require continued analysis of the concepts, the data base, the relationships and the factors related to the understanding of a system and structuring all of these into a common framework. This is an evolutionary process; the framework will undergo successive degrees of refinement via organized lists of the variables, organized lists of the processes, organized lists of the controls, relational diagrams, flow-oriented diagrams, listings of factors affecting flows and analysis of the nature of the relationship of factors affecting flows.

In introducing these concepts clarification of working terminology is necessary. The following sections discuss important concepts and terms.

1. The Concept of "Ecosystem"

The term "ecosystem" relates both to a concept and a spatial unit. In its use as a concept, the term means a system resulting from the integration of all living and non-living factors of the environment and biotic-abiotic complexes. The ecosystem concept necessitates looking beyond a particular biological entity or variable. In its use as a spatial unit, the term refers to a particular unit of landscape or seascape and is therefore geographic in nature.

The functions of an ecosystem include transformation, circulation, accumulation of matter and the flow of energy through and within organisms by means of biotic activities and natural physical processes. Two specific functional processes include photosynthesis and decomposition. More general functional processes include herbivory, carnivory, parasitism and symbiosis.

2. Concepts of "Variables" and "Processes"

A framework is needed for incorporating knowledge about the ecosystem's plant, animal and soil components. In a systems approach applied to such an environmental problem, "variables" and "processes" must be differentiated.

Variables represent the components of the system which can be measured in units. Such units might include the amount of plant material, or biomass, in a given area at a given time or the amount of water in the soil at a given depth in the profile at a given time for the area. These are the "state variables" of the system. The "state of the system" is specified by defining the state variables of the system, such as soil water levels, herbage biomass and animal numbers.

There are "external" or "driving variables" that can be distinguished from the system state variables. The driving variables are "outside" the system but affect the performance "inside" the system. Important external or driving variables from a biological viewpoint include precipitation, solar energy input and wind. Driving variables, as such, are measured outside of the zone extending from well below the surface to above the vegetation canopy.

Processes account for the flows of matter or energy from one state variable to another and are measured in rates. These processes may be physically controlled or physiologically controlled. Examples of physical processes can include infiltration and weathering. Examples of physiological processes include photosynthesis and herbage-consumption rate. Matter may be characterized as water, carbon, nitrogen, numbers of individuals or dollars. As one might expect, some overlap between variable and process exists with respect to certain elements of the environment. For example,by definition precipitation is a variable since it is measured in units. However, a rate can be attributed to precipitation. When precipitation is spoken of as occurring with some rate it becomes a process. Similar examples of changes in the nature of the elements can be found in any lists of variables for any element that can be measured in units that can also be given a rate. The reverse is not necessarily true. For example, one can speak of the weathering process but have difficulty in measuring weathering in units.

Man's activities commonly influence processes. By adding fertilizer to the soil, man may change the level of a state variable of soil nutrients, thus affecting the rate of the process of plant growth. Man also influences the level of state variables in the system, e.g., he may remove biomass of organisms via harvest.

This conceptual framework for distingushing between driving variables, state variables and processes is sufficiently general to allow conceptualization of biotic, sociologic, political and economic factors within the same structure.

3. Concept of Habitat Niches

The term "niche" refers both to the role of the organism in the community (functional niche) and to a subdivision of the environment occupied by the species. No two species can occupy exactly the same niche in the environment but there may be considerable overlap in the niches for different species. A community is a naturally occurring assemblage of plants and animals living in the same environment. These

plants and animals may be mutually sustaining and interdependent, constantly fixing, utilizing and dissipating energy. Ecological theory suggests that the more niches there are to occupy, the more specialized and diversified the occupants become. The more complex the community is in this way, the more stable the ecosystem is to perturbations.

The extent of the spatial niche of key organisms in the system is important in understanding what portion of the total area they affect. The functional niche of these key organisms is important in determining how they impact other biotic components and the abiotic part of their environment.

4. Man as a Controller

In a simplified view of an ecosystem there are driving forces (defined or external variables), biotic components and abiotic components. The biological components or biomass is segregated into three categories--producers, consumers and decomposers. Man becomes a special fourth category of "harvestors and manipulators." In resource management man is both a spectator of and participant in the functioning of ecosystems. Man manipulates these systems to convert energy to forms useable by him. Man exerts this impact through modifying the levels of the state variables or through modifying the processes, or both.

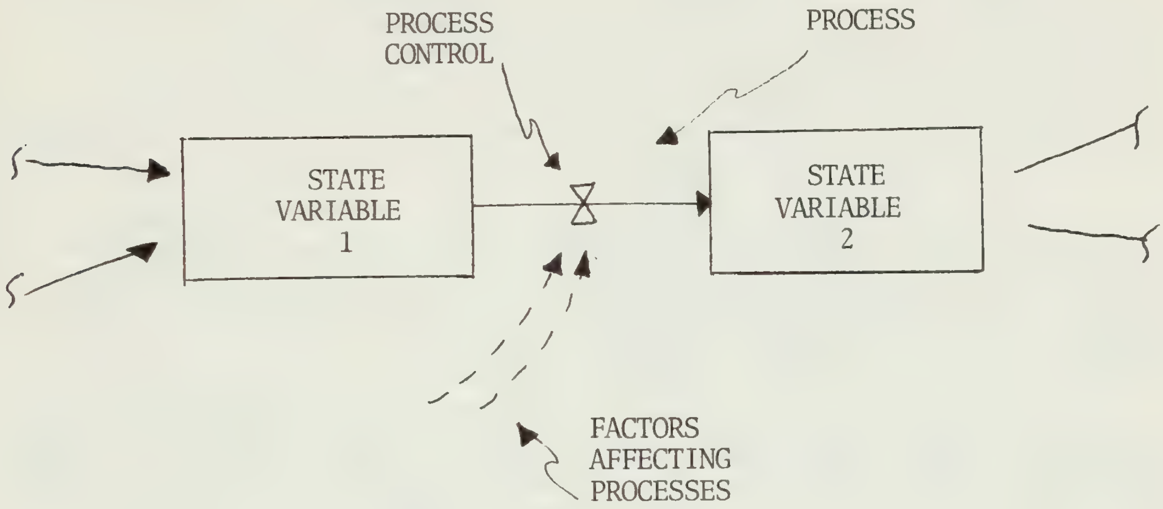
5. Some "Cause-and-Effect" Relationships

The majority of the preliminary biological studies (see Chapter V) are designed to provide baseline information. The major focus in these studies is to assess the abundance and distribution of terrestrial and aquatic plants, animals and communities. Such information is essential. Without detailed analysis, however, it provides little knowledge on "cause-and-effect" relationships.

In the conceptual structure discussed herein, it is noted that processes are the major phenomena accounting for the transfer of matter and energy within the system. Each process is controlled by one or more state or driving variables in the system. Thus, to detect cause-and-effect relationships one must know the structure of the system and the way the components affect each other. To know the structure of the system requires defining the variables within the system and showing their causal pathways. Secondly, it is important to know the form and relative magnitude of the influence of a variable upon a process.

If one knows the levels of the variables at a given time and the manner in which they affect a process, then it is possible to calculate the levels of the process at the next period of time. This allows predictions in the system under naturally occurring conditions of variable weather and under man's manipulation.

These cause-and-effect relationships may be illustrated in flow diagrams:



In such diagrams the state variables are the boxes. The processes accounting for the flows are the solid directional arrows. Each process has a control or series of controls on it as shown with dashed lines with arrows.

6. Potential Utility of a Conceptual Framework

The type of conceptual framework outlined above provides a useful tool in synthesizing and interrelating information obtained in the various baseline studies. It also provides a structure in which information about the plants, animals and physical features of the system derived from literature analysis and from study of agency records can be integrated. If one knows the functional relationships among the variables, predictive calculations can be made. Both quantitative and qualitative predictions may be made on the system's response to various degrees of human manipulation and intervention. Thus, the manager or decision maker can examine the future consequences of activities.

B. Concepts of Structural Units in the C-b Area

The primary purpose of analyzing structural units in the C-b area is to determine eventually the impacts of various human manipulations on the system.

In Chapter VIII an analysis is made of the visual characteristics of the major physiographic sections of the Colorado Plateau Province. The Uinta Basin Section is subdivided into various important subtypes

such as the Piceance Basin, Book Cliffs, Roan Cliffs, Colorado River Valley, Grand Mesa, Grand Hogback, Colorow Mountains, Flattops and Cathedral Bluffs-Douglas Creek. Within the confines of the Piceance Basin there is considerable variation in landform, rockform, vegetation and waterforms. A cross section of the topographic maps of the region can distinguish four major regional landscape units as follows in their order of aerial extent: ridgeland and upland plateaus, slopes, bottomland floodplains and stream courses. These subdivisions make up progressively less of the total area of the C-b Tract.

Within the various landscape units are found one or more major plant communities, as defined in Chapter V of this report. Dominant species of plants are defined in each of these 14 community vegetation types. Each of these types may occupy areas from a few hectares up to hundreds of hectares in one contiguous unit.

Also in Chapter V are studies of important species and groups of animals in the C-b area. Examples are shown in Table VII-1 of the distribution and important habitat requirements of key species. In many instances the home range of a given animal species exceeds the limit of one habitat type, both in its preference throughout the day or season of the year and in the area necessary to sustain life for the species involved.

The following sections illustrate examples of spatial scales of concern on-tract in relation to populations of key organisms. In effect, we are beginning here the definition of the spatial niches of the organisms. To begin this conceptualization we define microunits, mesounits, and macrounits in a somewhat overlapping manner. These are shown in Figure VII-1 in relation to regional landscape, community and niche concepts mentioned elsewhere in this report.

1. Microunits

These are units of small spatial extent in which certain groups of organisms live and die or perform key life processes. Initial examples and discussion are provided here on "microhabitats" as these pertain to plants as well as animals.

The study of vegetation on Tract C-b is focused at a spatial level greater than one of microunits or microsites; however, some important microsites occur and to some degree characterize the various vegetation types. In the chained areas, for example, the manner in which the trees have been felled and dragged into windrows has caused microsite differences between the windrows and open areas. Not only are microclimatic parameters such as wind speed, solar radiation and precipitation altered but also grazing patterns are altered by the felled trees. Trampling of windrow areas by both livestock and deer is apparent.

In the pinyon-juniper woodlands a pronounced difference in sites of litter accumulation is very apparent. Leaf litter from the pines and junipers is concentrated at the base of each tree in the form of a mound which has its greatest depth at the tree base and becomes thinner toward

TABLE VII-1.

Distributions and Habitat Requirements of Key Animals
On Oil Shale Lease Tract C-b

ANIMAL SPECIES	MICROUNITS Significant Microhabitat Requirements	MESOUNITS Characteristic Occurrences On Tract C-b: Aquatic & Reparian Areas	Agricultural Meadows	Bottomland Sagebrush	Lower Slopes & Bunchgrass	Rimrock	Pinyon-juniper Woodland	Chained Rangeland	Upland Sagebrush	Mixed Mountain Shrub	MACROUNITS Required and Migrational Distributions
MAMMALS:											
Mule deer	Lateral draws and lower south-facing slopes during severe winter weather	X	X	X	X	X	X	X	X	X	Higher elevations during summer
				(October-May)							
Coyote		X	X	X	X	X	X	X	X	X	Widely distributed; home ranges extend outside Tract boundaries
Bobcat	Rimrock and lateral draws are used as den sites			X	X	X	X	X	X	X	
Desert Cottontail		X	X	X	X	X	X	X	X	X	
White-tailed jackrabbit									X	X	
Bushy-tailed woodrat					X	X	X				
Northern pocket gopher			X								
Deer mouse		X	X	X	X	X	X	X	X	X	
Least chipmunk				X	X	X	X	X	X	X	
Montane vole	Grassy vegetation	X	X								
BIRDS:											
Golden eagle	Nest site: Cliff with ledge, pothole, or shallow cave; minimal size: 30.48 x 30.48m					X	X	X	X	X	Home range: minimum various terrain
Red-tailed hawk	Nest site: cliff with ledge, pothole, or shallow cave, minimal size: 2.19 x 15.24m; or sturdy tree, minimal size 6.10m	X	X	X	X	X	X	X	X	X	Open, rolling country including mixed shrub, sagebrush, and meadows, minimal size, 13km^2
Marsh hawk	Nest site: grassland, agricultural meadow or pasture, minimal size .4 ha	X	X								Uplands adjacent to Tract C-b
Great horned owl	Nest site: cliff with ledge, pothole, or shallow cave, minimal size 12.19 x 15.24m; or sturdy tree, minimal size 6.10m	X	X			X	X	X			
Rough-legged hawk		X	X								Migrates and nests in the Arctic.
						(Winter)					
American kestrel		X	X	X	X						
Mallard	A pond of at least 6.10m diameter required for courtship and post hatching period	X									

UNITS	SCALE	EXAMPLE UNITS
MACRO	Regional	Piceance Basin Book Cliffs Colorado River Valley . . . (see text)
	Landscape	Ridges and Upland Plateaus Slopes Bottomland Floodplains Stream courses
MESO	Community	Pinyon-juniper woodland Chained pinyon-juniper rangeland Upland sagebrush Bottomland sagebrush . . . (see quarterly Summary Reports)
MICRO	"Niches"	Tree slash piles Eyries Lateral draws Litter hummocks Springs & seeps

Figure VII-1 CONCEPTUAL ORGANIZATION OF MICRO, MESO, & MACRO SPATIAL UNITS FOR VIEWING ECOSYSTEM COMPONENTS

the outer perimeter defined essentially by the tree canopy. Areas away from the individual trees are mostly free of tree litter. These litter "hummocks" are very different from the non-litter areas and few vascular plant species are capable of growing in the thick needle accumulations. Many of the litter hummocks are nearly covered with a species of moss which usually does not occur on non-litter areas.

A similar feature can be seen in the upland-sagebrush communities. Litter and soil particles accumulate at the bases of the sagebrush plants and provide a site which appears to be more suitable for the growth of mosses and lichens. The same species of moss which occurs on the pinyon-juniper litter hummocks also occurs on the litter accumulations in sagebrush communities. Additionally, several other moss species and numerous lichens grow on these sites.

There are special habitat requirements that must be satisfied before a species can reproduce in a general region. For example, if all structural habitat requirements except that of a nest location are available in a 20 square mile area (territory size), a golden eagle still cannot reproduce. Characteristics of the appropriate nest site substrate should be considered on a microunit level. It is one dimension of the habitat niche.

In an arid area aquatic organisms occupy habitats on a microscale. There may be seasonal migration, however, of some of the larger aquatic organisms. Some examples of spatial scales for aquatic organisms follows.

Species	Common Name	Estimated Home Range (Spatial Scale)	Productivity Gm/ash-free dry wt./m^2/day	Habitat
Periphyton (all species)	Diatoms, Algae, etc.	Attached (Sessile)	0.002-2.0297	All types

Periphyton are identified as to species in the field studies. Quantitative data are computed for all species combined. Major groups collected include: Green algae (Chlorophyceae), Diatoms (Bacillariophyceae), Blue-green algae (Cyanophyta) and Euglenids (Euglenophyceae). Artificial substrates used in measuring productivity by the Biomass Accumulation Technique (APHA, 1971). The main habitat types of concern are small, clear, spring-fed streams, lakes, larger streams (turbid at times) and rivers.

The habitat scales of benthic organisms are as follows:

Taxon	Common Name	Estimated (ha) Home Range	Number Per m^2	Biomass (gm) Per m^2	Habitat
Benthos (all species)	Aquatic Insects	0.1	215-14,483	0.0839-20.0911	A,B,C,D
Diptera	True flies	0.1	0-13,116	-	A,B,C,D
Plecoptera	Stoneflies	0.1	0- 968	-	A,C,D
Tricoptera	Caddisflies	0.1	0- 1,915	-	A,B,C,D
Coleoptera	Beetles	0.1	0- 430	-	A,B,C,D
Ephemeroptera	Mayflies	0.1	0-12,226	-	A,B,C,D
Other		0.1	0- 5,961	-	A,B,C,D

The habitat types noted above are:
A-Small, clear, spring fed streams; B-Lake; C-Larger stream (turbid at times); and D-River habitat.

Benthic invertebrates are identified to the lowest taxon (usually genus) in field studies. Most data are tabulated by order or for all taxa combined. Others encountered in addition to the major groups listed above include: Odonata (Damselflies and Dragonflies), Hemiptera (True bugs), Homoptera (Terrestrial - aphids), Lepidoptera (Aquatic caterpillars), Amphipoda (Scuds), Gastropoda (Snails) and Pelecypoda (Clams). Direct count and weighing are made on samples collected by a Surber sampler. Biomass determination have been made for all species combined.

The important fish of the C-b Tract are as follows:

Species	Common Name	Estimated Home Range	Number Per 100 m Stretch of Stream	Grams/m^2	Habitat
Salvelinus Fontinalis	Brook Trout	*	1-18	0.3-5.4	A,B,C,D
Catostomus platyrhynchus	Mountain Sucker	*	17-105	1.0-13.1	A,C
Rhinichthys osculus	Speckled Dace	*	5-95	0.2-1.7	A,C,D

The habitat types noted above are: A-Small, clear, spring-fed stream; B-Lake; C-Larger stream (turbid at times); and D-River, depth over 1.32M in places, swift flow, width over 12.19M.

Other species encountered on an irregular basis include: Brown trout (Salmo trutta), Rainbow trout (Salmo gairdneri), Mountain whitefish (Phrosopium williamsoni), Flannelmouth sucker (Catostomus latipinnus), Mottled sculpin (Cottus bairdi). Population estimates were made using Zippin's formulae. Weights are based on average weight. Tagging studies have shown most of these fish stay in the same general stretch of stream. However, results are inconclusive. They are known to migrate at certain seasons for spawning and wintering.

2. Mesounits

The recognizable vegetational mesounits on Tract C-b fall into the category of plant communities. These units, listed below, have been the focus of the vegetation study within the Tract C-b area. Descriptions of these are presented in Chapter V of this report. They are:

Pinyon-juniper Woodland
Chained Rangeland
Upland-Sagebrush Community
Bottomland-Sagebrush Community
Douglas-fir Forest
Mixed-Mountain Shrublands
Bunchgrass Community
Rabbitbrush Community
Greasewood Community
Ponds
Marshes
Riparian Areas
Hay Meadows
Great-Basin-Wildrye Community
Annual-Weed Community

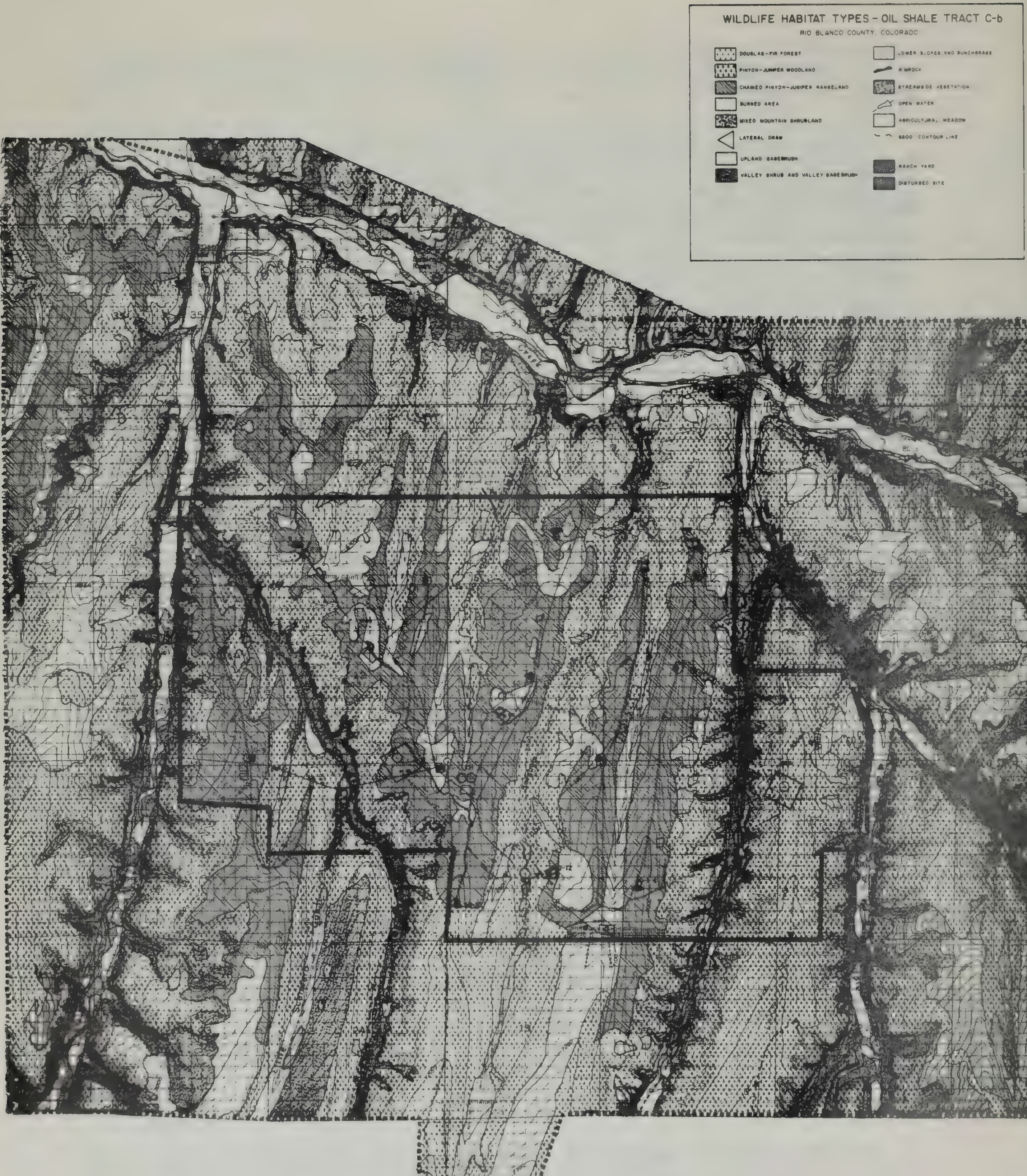
The distributions of animal species cannot always be adequately classified in terms of plant communities, since physical features (rimrock) as well as dissimilar vegetational units often more accurately define the determinants of observed distributional patterns. The following nine major habitat types are recognized for the Tract C-b area, and a number of smaller subunits have been defined as well (Figure VII-2 and Table VII-1).

Aquatic and riparian areas
Bottomland sagebrush
Rimrock
Chained rangeland
Mixed-mountain shrub
Agricultural meadows
Lower slopes and bunchgrass
Pinyon-juniper woodland
Upland sagebrush

3. Macrounits

The vegetational macrounits (Table VII-1) were constructed by combining major plant communities which are physically similar. The macrounits correspond well with major topographic units except for the

Figure VII-2



WILDLIFE HABITAT TYPES - OIL SHALE TRACT C-b
RIO BLANCO COUNTY, COLORADO
DOUGLAS-FIR FOREST
PINYON-JUNIPER WOODLAND
CHAINED PINYON-JUNIPER RANGELAND
BURNED AREA
MIXED MOUNTAIN SHRUBLAND
LATERAL DRAW
UPLAND SAGEBRUSH
VALLEY SHRUB AND VALLEY SAGEBRUSH
LOWER SLOPES AND BUNCHGRASS
RIMROCK
STREAMSIDE VEGETATION
OPEN WATER
AGRICULTURAL MEADOW
6800 CONTOUR LINE
RANCH YARD
DISTURBED SITE

chained rangelands which constitute a unit produced by man's activities. The chained area could be combined with the upland-shrub communities because of its general physiognomic similarity. The vegetational macrounits are Woodland, Upland-Shrub Communities, Bottomland-Shrub Communities, Chained Rangelands and Meadows.

With respect to animals and macrounits, consider those animal habitats present in the Tract C-b area combined with habitat found outside the Tract C-b vicinity. Two types of species should be considered in examples of this spatial scale. The first type is the permanent resident (or breeding resident) having such a large territory or zone of activity as to encompass a broad spectrum of community types. The second type involves migratory species which spend the winter on Tract C-b habitat types and the breeding period at higher, nearby elevations. Included in the macrounit scale are only those migrants that undergo localized altitudinal movements (keeping the regional context) rather than those that undergo latitudinal movements, i.e., a continental context, such as a rough-legged hawk breeding in the arctic tundra but over-wintering on Tract C-b.

C. Concepts of Organismal and System Function

A system is a set of structural units organized to function in a particular way. The system of concern may be an organism, a species population or a total ecosystem. Ecosystem or organismal functions are attributed to individual processes or combinations of processes. The concept of processes has been described as the mechanisms by which matter and energy are moved from place to place (or variable to variable) within the system. The following subsections elaborate on this concept, give examples of units of measure, a conceptual hierarchical structure for process descriptions and illustrate short-term, medium-term and long-term processes occurring in the C-b Tract.

1. Function and Process

Numerous physical and physiological phenomena operate within ecological systems to transfer matter and energy from one part of that system to another. Example processes are elaborated in Table VII-2. This listing of processes, although incomplete, illustrates the complex nature of ecological systems. Examination of the results in Chapter V shows that few studies are involved in direct process measurements as listed in Table VII-2. However, in many instances, it is possible to infer these process rates at a different hierarchical level of resolution from measurements of the state variables. It is also possible to calculate the process rates in some instances by changes in the variables. Thus, for example, in Chapter V the process of plant production at a medium level of resolution was calculated from changes in standing crop measurements over time. This at best, is an approximation as noted in the following diagram:

Table VII-2 EXAMPLES OF PROCESSES OPERATIVE IN THE ECOSYSTEMS OF THE C-b TRACT

ABIOTIC PROCESSES

Heat Transfer Process:

Radiation	Atmosphere	to	Soil
Conduction	Atmosphere	to	Soil
Convection	Atmosphere	to	Soil
Radiation	Atmosphere	to	Plant
Conduction	Atmosphere	to	Plant
Convection	Atmosphere	to	Plant
Radiation	Atmosphere	to	Animals
Conduction	Atmosphere	to	Animals
Convection	Atmosphere	to	Animals
Conduction	Soil Layer	to	Soil Layer
Conduction	Soil Surface	to	Animals
Radiation	Soil	to	Plant

Water Transfer Processes

Precipitation	Atmospheric Water	to	Surface Water
Evapocondensation	Atmospheric Water	to	Surface Water
Evaporation	Soil Water	to	Atmospheric Water
Interception	Atmospheric Water	to	Plant Surface Water
Snow Melt	Solid Water	to	Liquid Water
Infiltration	Soil Surface Water	to	Soil Layer Water
Runoff	Soil Surface Water	to	Stream Channel Water

Nutrient Transfer Processes:

N_2 Fixation	Atmosphere	to	Soil NH_4^+ and NH_3^-
Mineralization	Soil Organic Matter	to	Soil NH_4^+ P
Immobilization	Soil NH_4^+	to	Soil Organic Matter
Exchange	Soil Mineral Lattice	to	Soil NH_4^+ Food
Oxidation	NH_4^+	to	NH_3^-
Humification	Dead Root N P	to	Soil Organic Matter N P
Ammonification	Dead Root N P	to	Soil NH_4^+
Humification	Litter N	to	Soil Organic Matter
Transformation	Insoluble P	to	Soluble P
CO_2 Diffusion	Soil Layer	to	Soil Layer
Mineral Decomposition	CO_2 Soil Storage	to	Soil Solution CO_2
Buffer Transformation	CO_2 Soil Storage	to	Soil Solution

Table VII-3 EXAMPLES OF PROCESSES OPERATIVE IN THE ECOSYSTEMS OF THE C-b TRACT

BIOTIC PROCESSES

Producer Processes:

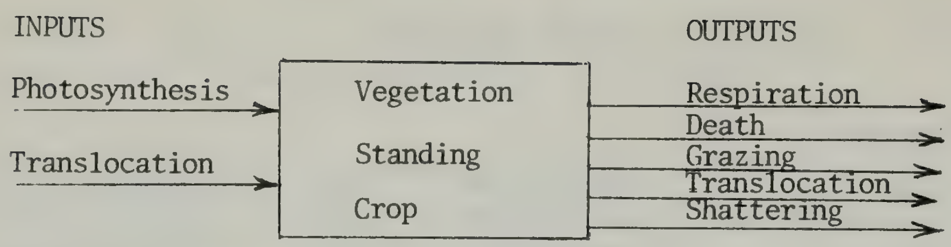
Shattering	Standing Dead	to	Litter
Physical Decomposition	Standing Dead	to	Litter
Shattering	Standing Live	to	Litter
Expiration	Standing Live	to	Standing Dead
Expiration	Live Root	to	Dead Root
CO_2 Diffusion	External Atmosphere	to	Stomatal Atmosphere
C Fixation	Stomatal Atmosphere	to	Organic Compound
Translocation	Leaf	to	Stem
Translocation	Stem	to	Seed
Translocation	Stem	to	Crown Storage
Translocation	Crown	to	Root
Respiration	Stem	to	Crown Storage
Respiration	Root	to	Soil CO_2
Chemical Transformation	Labile	to	Nonlabile Compounds
Absorption	Soil Solution Nutrient	to	Live Root Nutrient
Exudation	Live Root Nutrient	to	Soil Solution Nutrient

Consumer Processes:

Diet Selection	Food Available	to	Food Handled
Ingestion	Food Selected	to	Food Consumed
"Wastetation"	Food Selected	to	Food Wasted
Storage	Food Selected	to	Cache
Transportation	Food Selected	to	Carried to Young
Digestion	Food Consumed	to	Food Digested
Defecation	Food Consumed	to	Feces
Metabolization	Food Digested	to	Food Metabolized
Urination	Food Digested	to	Urine
Eructation	Food Digested	to	Atmosphere
Transformation	Food Metabolized	to	Basal Metabolism
Transformation	Food Metabolized	to	Heat Maintenance
Transformation	Food Metabolized	to	Reproductive Tissue
Transformation	Food Metabolized	to	Milk
Transformation	Food Metabolized	to	Nonfat
Transformation	Food Metabolized	to	Fat
Transformation	Food Metabolized	to	Integument
Transition	Age/Sex $State_j$	to	Age/Sex $State_j$

Decomposer Processes:

Consumption	Aboveground Litter (Mulch)	to	Microbiota
Consumption	Belowground Litter, Humic Compound, Animal Residues, Dead Roots	to	Microbiota
Expiration	Live Active Microbiota	to	Dead Microbiota
State Transformation	Live Active Microbiota	to	Inactive Microbiota
Expiration	Inactive Microbiota	to	Dead Microbiota
Humification	Dead Microbiota	to	Humic Compounds
Extracellular Decomposition	Belowground Litter, Humic Compounds, Animal Residues, Dead Roots	to	Degraded Compounds



The examples in Figure VII-3 take some of the processes from Table VII-2 and array them into different levels of resolution--physiological, organismal and population. The upper part of the figure displays autotrophic processes. Those processes occurring within the living tissues of the organism are at the physiological level. Those processes involving the total organism, or major part of it, as well as those that do not involve the live organism, are at the organismal level. The processes at the population level generally are those including groups of organisms.

In the lower portion of Figure VII-3, an example is given of a similar approach at the heterotrophic level. Here the heterotrophic production process, at the population level, can be broken down into a series of processes at the organismal level. It is useful to conceive biomass gains or biomass losses as components of heterotroph production. This is because of the mobility of animals as compared to plants. Thus, through immigration or stocking of a given area with a particular species of animal (such as cattle) the biomass in the area can be increased greatly and rapidly. Similarly through destocking or emigration biomass may be removed. The other processes at the organismal level occur within the indigent organisms--growth to produce biomass gain, and body weight loss and death resulting in biomass loss. At the physiological level, growth may be because of accumulation of different types of tissues--reproductive, fat, muscle and integument. Similarly, for biomass losses, the same tissues may be involved but the flow is reversed. Mobilization of fat and transformation into other products (with a net expenditure of energy) results in a weight loss. Not as much energy can be obtained from one unit of fat when it is "burned" in the body as was required to produce and deposit that unit of fat.

Jointly, Table VII-2 and Figure VII-3 illustrate a beginning conceptualization of the processes that exist in the C-b Tract ecosystems and how they may be resolved into lower and lower levels of resolution. In conceptualizing the system and its operation, it is not necessary to have all processes represented at a low level of resolution. The examples shown in Table VII-2 generally use the higher levels of resolution. The examples shown in Figure VII-3 indicate how these increases may be grouped into lower and yet lower levels of resolution. Generally, a process description at a high level of resolution is considered a detailed one. At low levels of resolution, the processes are considered approximate representations. Either type of representation may be adequate for a given purpose. In general, for approximate representations longer time steps or time scales are used whereas detailed representation shorter time steps are used in calculating changes of the state variables.

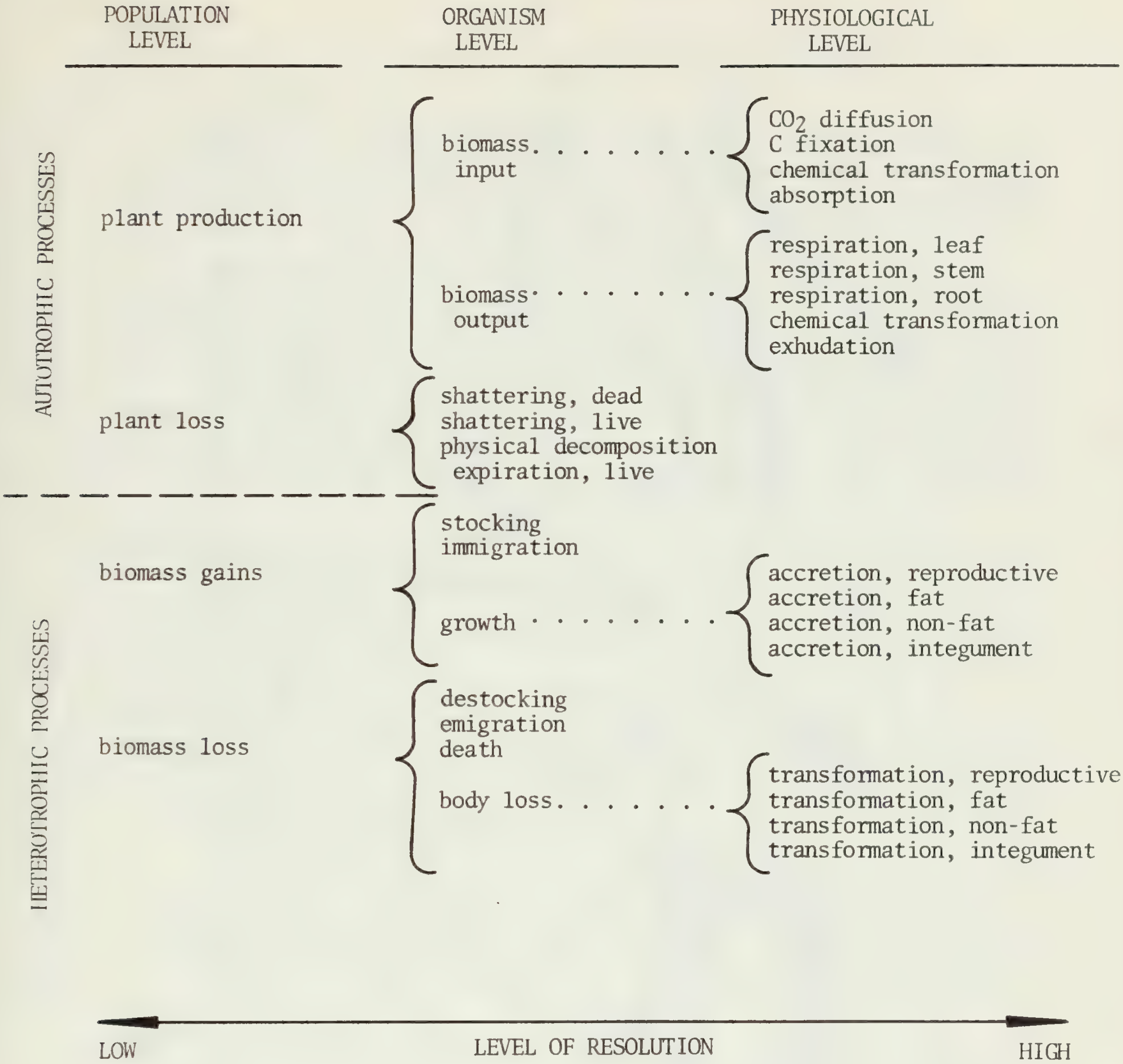


Figure VII-3 EXAMPLES OF HIERARCHIES OF PROCESSES AT DIFFERENT LEVELS OF RESOLUTION

2. Time Scales for Processes

Many processes shown in Table VII-2 or Figure VII-4 require a short-term time scale, perhaps of less than one day up to one month. At lower levels of resolution the time step for a process may be in the range of one month to several years. Still longer time steps are important in the successional process, which may take even centuries for completion.

Successional changes in vegetation may be initiated by either internal or external influences. External factors such as drought, fire or human activities can be catastrophic and alter plant communities from dynamic-equilibrium states to non-equilibrium states. Fires, for example, can destroy woodlands and produce conditions intolerable for climax-species growth and reproduction. In such cases the burned sites are colonized by species that tolerate the post-fire environmental conditions. The vegetational cover produced by these pioneer species alters the micro-environment and produces conditions favorable for species unable to become established immediately after the fire.

The amelioration of environmental parameters by pioneer species initiates internal changes in the vegetation brought on by the plant species themselves. This process of replacement continues until the community reaches a state in which the species that dominate the community are the same ones that replace older individuals when they die.

The primary agents of change acting on the vegetation of Tract C-b are fire and human activity. Fires in the pinyon-juniper woodlands have been very localized. They are devastating and recovery is a slow process in these woodlands. The chaining program has had a far greater areal impact on the woodlands. The two processes (fire and chaining) both cause destruction of the woodlands and initiate secondary succession. Recovery of the woodland vegetation may require 200 years.

Other human activities related to industrial activities have produced small, localized,disturbed sites that are in various states of successional recovery. Grazing practices have altered valley shrub communities and apparently have favored the development of communities dominated by rabbitbrush.

Long-term, climatic changes over the past 500 years appear to have had little effect on the pinyon-juniper woodlands. Reductions in tree growth rates during period of drought can be observed in the dendrochronological record; the reader should consult Section H of Chapter V for more detail.

D. Some Key Structure - Function Interrelationships

Certain of the principal structure-function interrelationships occurring on and close to Tract C-b are described below. These generally can be categorized as vegetation-environment and animal-environment relationships. Within each of these categories relationships to some key abiotic and biotic factors are treated. Obviously overlap exists;

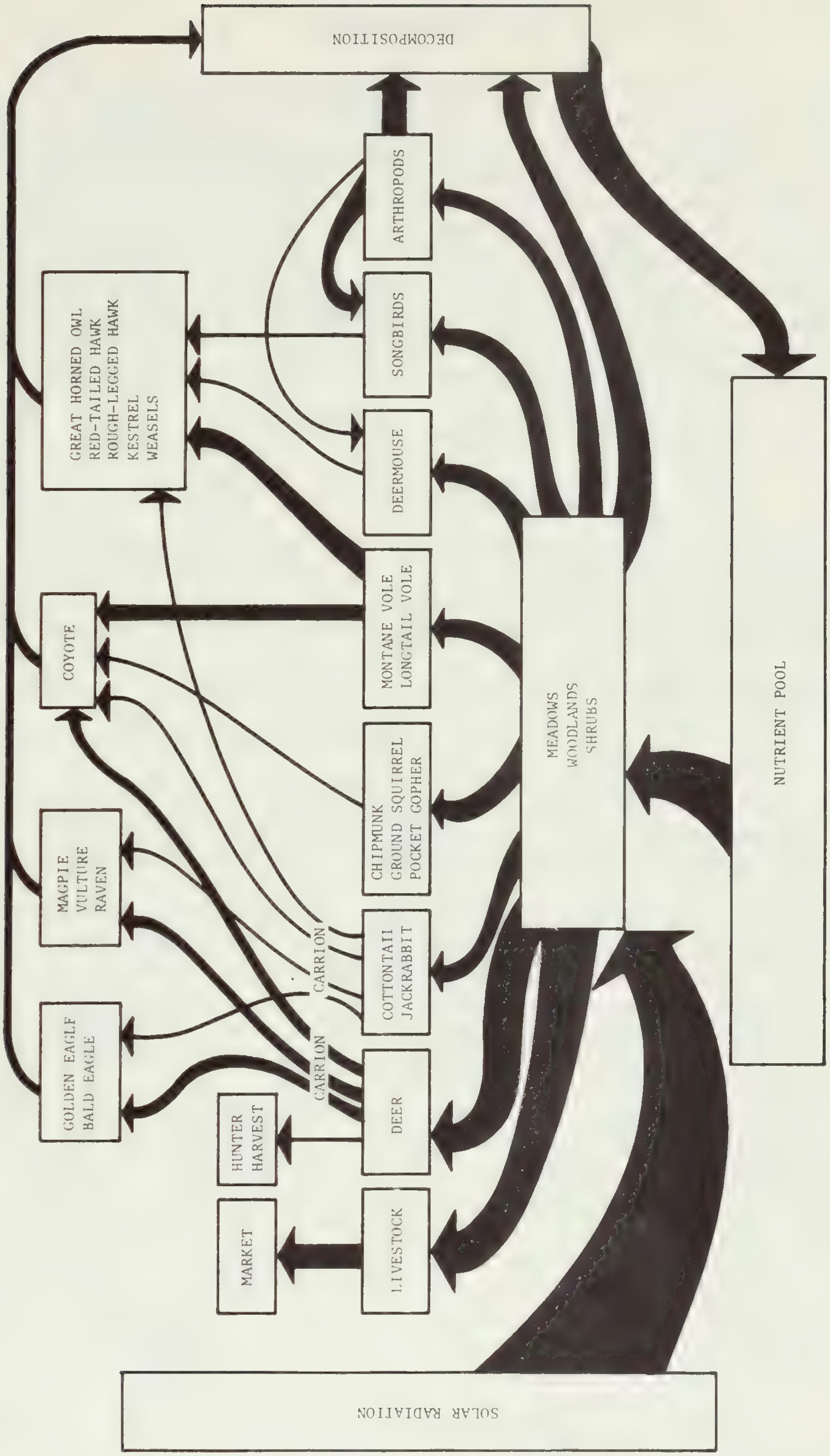


Figure VII-4 PRINCIPAL RATES OF ENERGY TRANSFER IN THE TRACT C-b STUDY AREA

for instance, vegetation-herbivore interactions are addressed under the vegetation category rather than under animals.

Earlier, examples of different spatial units, which form the "niche," community, landscape and regional theaters for structure and functional processes, were discussed. A generalized discussion of certain structure-function relationships is presented and relates in part to Figure VII-4 which is an illustration of the principal routes of energy transfer in the Tract C-b Study area. Difficulties of characterizing interrelationships concurrently being expressed at a number of spatial scales are complicated by the internal interrelatedness and low resolution of the magnitudes of most processes occurring in Tract ecosystems (Figure VII-3). However, as the conceptualization of ecological relationships on Tract C-b improves better predictability of cause-and-effect phenomena will result.

1. Vegetation-Environment Relationships

a. Relationships to Abiotic Factors

A necessary step in understanding the Tract ecosystems is to determine how prevailing abiotic factors may dictate the distribution and pattern of vegetation. Vegetation patterns, in turn, control the distribution and habitat-utilization characteristics of most animal species.

The generalized schematic:

$$\begin{tikzcd} & \text{Climate} \arrow[dl] \arrow[dr] & \\ \text{Vegetation} \arrow[rr, shift right] & & \text{Soils} \arrow[ll, shift right] \end{tikzcd}$$

is a simplistic expression of the relationship between vegetation and the environment. As the schematic implies, both vegetation and soil are causally determined by climate and secondarily by their own interrelationships.

The principal parameters of climate and microclimate that influence vegetation and soils are temperature and precipitation. Temperature regimes and moisture in soils determine weathering rates of the parent material and the types of vegetation which the soil can support. The effects of temperature in ambient air also interact with vegetation by influencing developmental events such as germination and flowering.

The principal characteristics of soils interacting with vegetation are morphological and chemical. Important soil morphological features include permeability, moisture, capacity and texture. These properties determine, to an extent, root penetration and moisture stress for plants. The entire nutrient regime of major, minor and trace elements constitutes the soil chemistry-vegetation interface. These elements have been listed and discussed in Chapter VI. Plant amendments such as dead fall and litter from leaves and bark integrate with soil chemical properties. Structural features of vegetation such as canopy cover and root form also influence the weathering characteristics of soils.

Figures VII-5 through VII-7 summarize precipitation, soil moisture and temperature data relative to vegetation. These figures have been constructed from data gathered in the four major vegetation types on the

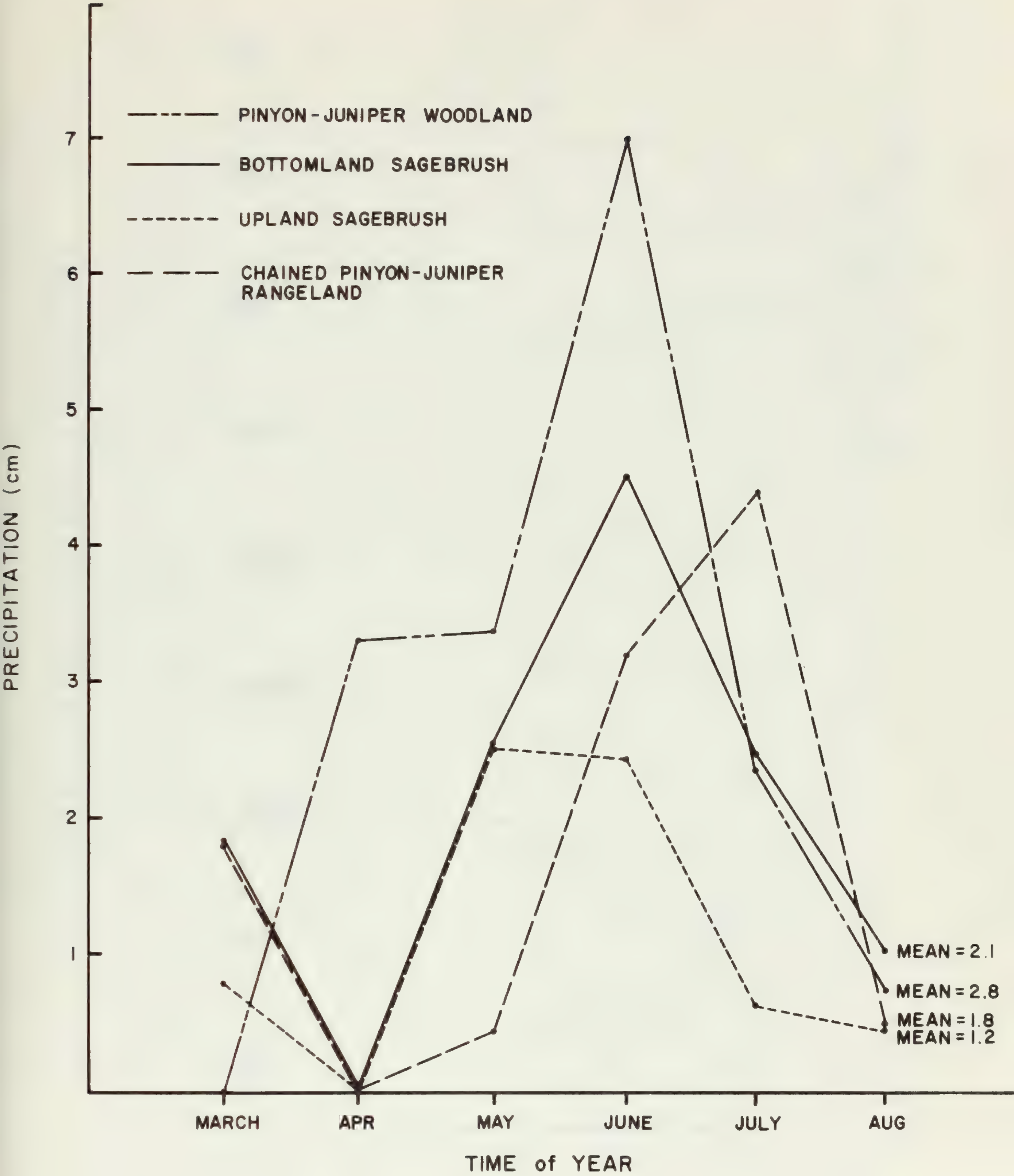


Figure VII-5. PRECIPITATION SUMMARY FOR THE FOUR MAJOR VEGETATION TYPES IN THE TRACT C-b STUDY AREA

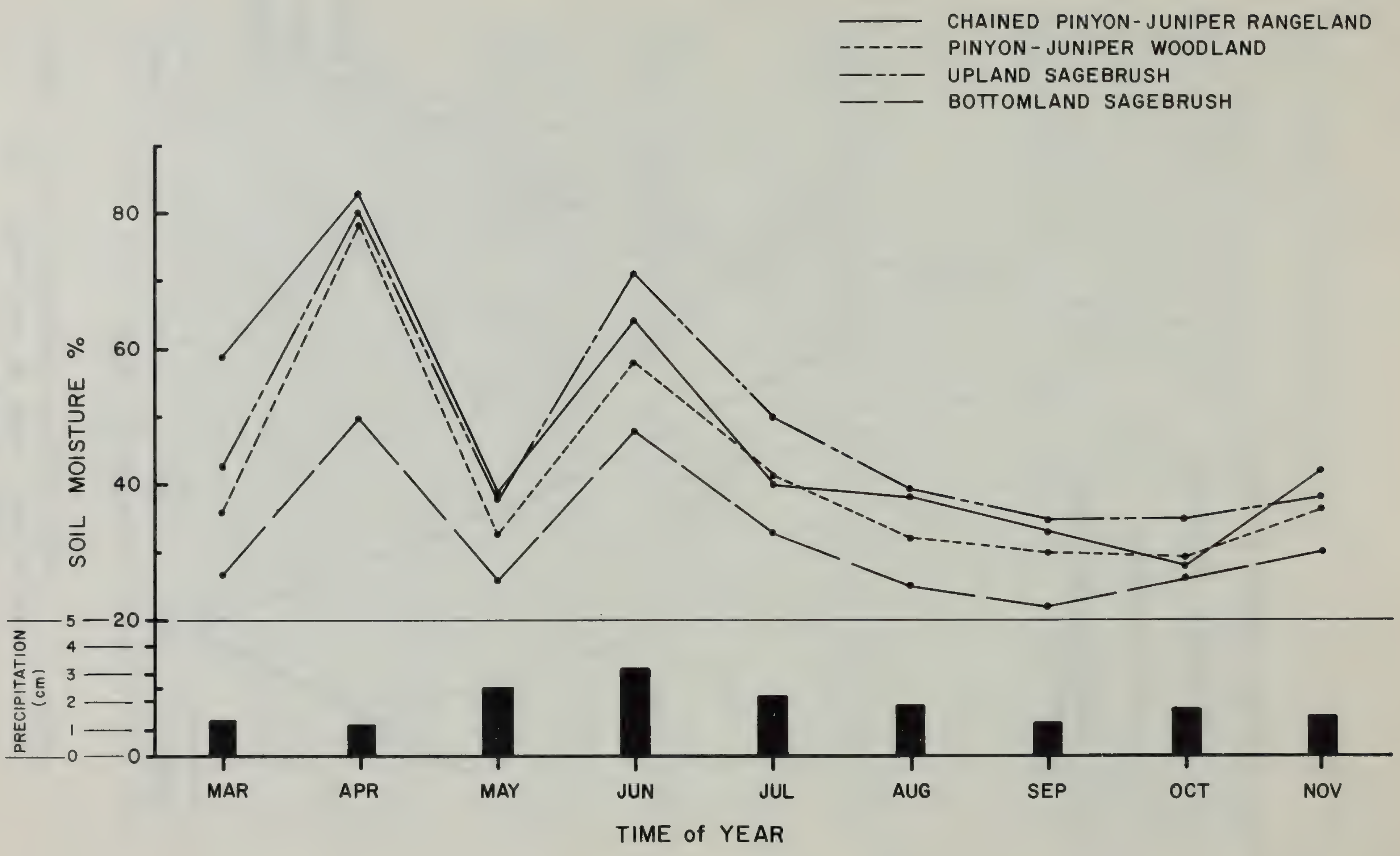


Figure VII-6 SOIL MOISTURE SUMMARY FOR THE FOUR MAJOR VEGETATION TYPES IN THE TRACT C-b STUDY AREA

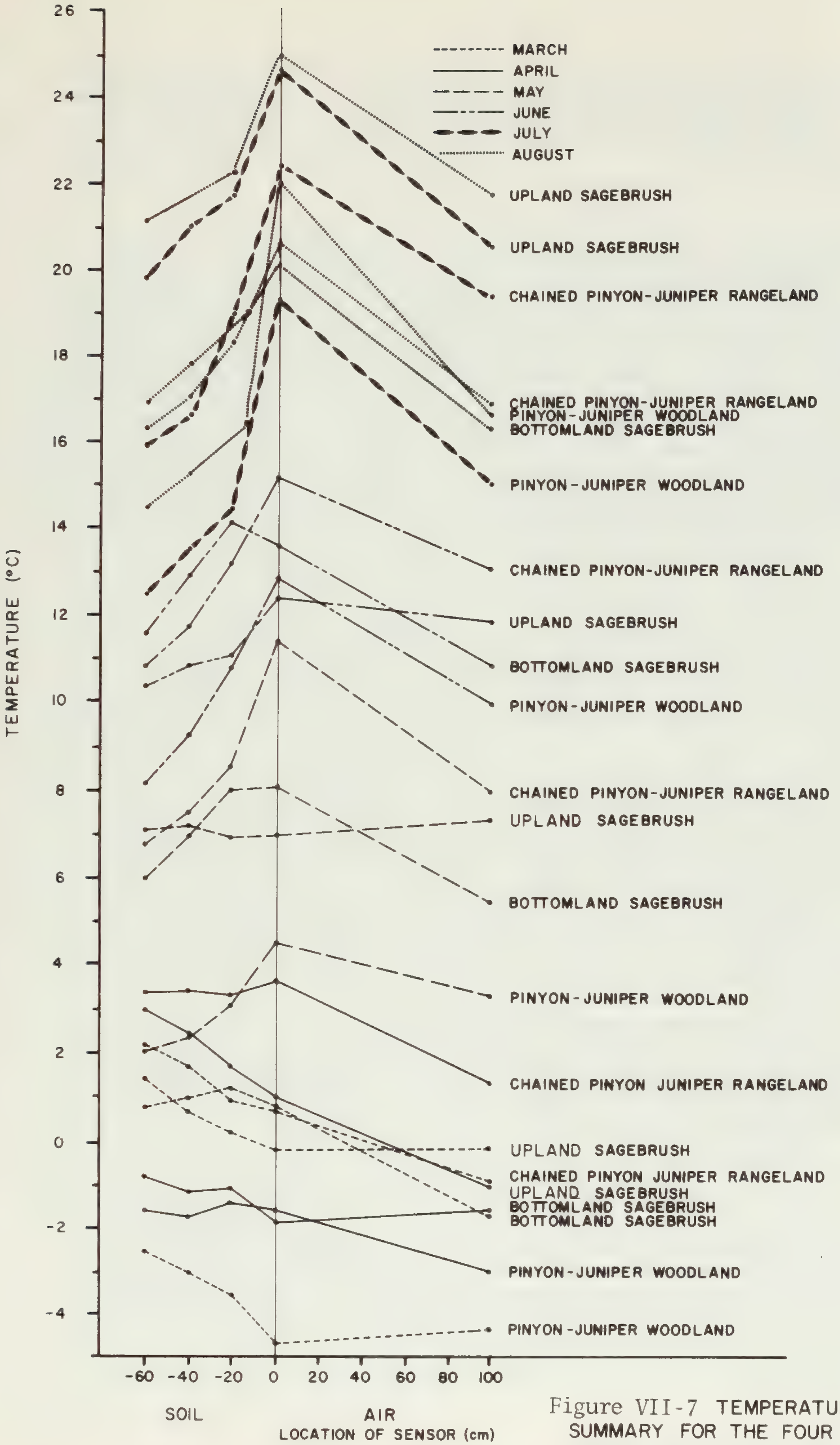


Figure VII-7 TEMPERATURE SUMMARY FOR THE FOUR MAJOR VEGETATION TYPES IN THE TRACT C-b STUDY AREA

Tract: pinyon-juniper woodlands, chained pinyon-juniper rangelands, upland-sagebrush sites and bottomland-sagebrush sites. Moisture, temperature and soil nutrient-vegetation relationships are briefly indicated in the following paragraphs.

(i) Moisture

The short-term precipitation record for the Tract does not reveal any evidence of precipitation trends which correlate with distribution of vegetation type. A portion of this record (for the period from March, 1975 through August, 1975) is shown in Figure VII-5. This figure illustrates the sporadic nature of rainfall over the Tract area which is probably typical of the region. Although pinyon-juniper woodlands received the greatest amount of precipitation for the short period of measurement (mean value of 2.8 cm), other records from spot-check stations demonstrated that other pinyon-juniper sites received less moisture than other vegetation types. Obviously, lack of long-term, Tract-specific data on precipitation variability in different vegetation communities prohibits conclusions. However, long-term averages of local precipitation should demonstrate little or no disparity across the Tract area.

Soil moisture data collected for the four, major, vegetation types from March through November 1975 are summarized on Figure VII-6. To a certain extent, these data reflect the nature of expected seasonal changes in the soil moisture regime within the vegetation types on the Tract. There is an overall tendency for soil moisture to be high in the early spring as a result of the infiltration of snow melt. Bottomland, big-sagebrush stands tend to dry out more rapidly than rangelands and woodlands and tend to remain drier through the summer months. This may be attributed to the fine-grained nature and tightness of the soils underlying these latter types. Such soils prevent rapid infiltration of water after rainfalls. The upland-sagebrush sites remain more moist than other sites through the summer, but do not respond as markedly to autumn precipitation as do the other vegetation types. The high soil moisture values in woodland sites during the spring emphasize the importance of winter snow accumulation to the growth of trees as reported in the dendroclimatological section included in Chapter V.

The low soil-moisture values in May for all sites are possibly the result of percolation of moisture through the lower soil strata, which were previously frozen, and of greatly increased water use by plants during the resumption of early season growth. Moisture increases in June are the result of early summer rains.

The soil-moisture data summaries compare favorably with field-capacity values (Figure VII-6). Pinyon-juniper woodlands and upland-sagebrush sites have the highest field-capacity values. The field-capacity data together with the soil-moisture data, indicate that (1) these soils are capable of holding substantial quantities of water, and (2) this water is available for plant growth at the period when

growth is resuming. The low field capacity value for bottomland-sagebrush sites is accompanied by low mean soil-moisture. Chained pinyon-juniper rangelands appear to be intermediate with respect to both soil moisture and field capacity.

(ii) Temperature

Figure VII-7 illustrates temperature profiles for the four, major, vegetation types on the Tract for the months of March through August. These profiles have been constructed from monthly mean values of continuous temperature data at the four sites. The values listed were collected at three soil depths, one surface location and one, free-air location.

All sites show two similar patterns with respect to differences in soil and air temperature. Soil temperature changes over a relatively narrow range in comparison to air-temperature changes between seasons. The seasonal change between spring and early summer shows an inverted relationship of soil temperature to surface and air temperature. This is the expected pattern of response resulting from the fact that soils gain and lose heat more slowly than air.

As a general observation, the most variable sites are the chained rangelands; the coldest sites are the pinyon-juniper woodlands. Bottomland- and upland - sagebrush sites are intermediate, the latter generally cooler during cold weather and warmest in hot weather.

Chained Pinyon-Juniper Rangelands

This is the warmest site of the four major vegetation types during cold seasons. The temperature differences between extremes in depth and height are the greatest of all sites. The behavior of the profile is markedly similar to that of the woodland site. This would indicate the overall similarity of primary controlling factors. The marked differences in actual temperature between these two types are attributed to the absence of a canopy on the chained sites increasing the effective level of solar insolation. The correspondence of behavior in temperature profiles in these two, structurally different sites is a good indication that the controlling factors on heat distribution in soils are texture and moisture content. In air factors that influence heat gain during daylight hours and heat loss at night are surface albedo, vegetation structures which stabilize air flow and topographic features which determine the direction and significance of cold air drainage.

Bottomland Sagebrush

The unique temperature feature of this type is the behavior of the subsurface temperatures. Instead of the gradual temperature decrease with depth characteristic of warm weather and the gradual increase with depth characteristic of cold weather, the extreme subsurface is colder than shallow layers during both warm and cold weather. The shallow soil layers are either warmer than the surface or about the same temperature.

The probable mechanisms responsible for this phenomenon are the poor mixing of air above the surface created by dense vegetation greater than one meter in height, the shading effect of this vegetation and the poor thermal conductivity of the soils under this community. A similar phenomenon occurs during winter in woodland sites. Snow pack in both of these sites reduces the absorption of energy and contributes to the insulating effect. Penetration of moisture in spring increases heat conductance of the shallow soils in the bottomland-sage sites since wet soil conducts heat better than dry soil. Thermal conductivity of the bottomland sites is again reduced in summer as the soils dry out. This response is eliminated during the warm, summer months.

Lower average air-temperatures at one meter, in contrast to upland-sagebrush sites, are the result of cold air drainage in bottomlands. Apparently, the vegetation height is responsible for limiting the effects of cold air drainage to levels above the shrub canopy.

Upland Sagebrush

Air temperature records from these sites show more vertical mixing than do data from the other sites. This is shown by a small temperature difference between the surface and free air at one meter height. This relationship appears to be the result of the low profile of the vegetation which has little retardent effect on air movement. In contrast the other sites have, to some degree, a higher vegetation profile which significantly channels and buffers moving air.

The upland-sagebrush type has a generally weak temperature profile. Although temperatures are intermediate with respect to other sites, the difference in temperatures at all levels is significantly less than in other measured sites. The greater response of soils at depth to surface heating is apparently the result of moist, fine textured soils. During the warmer summer months (July and August) the profile becomes better developed as a result of high insolation at the surface.

Pinyon-juniper Woodlands

The data collection site for pinyon-juniper woodland is located on a narrow ridge. The woodlands at this site have an open understory. Although this site may differ from dense understory woodlands and woodlands of an open understory type on east and west-facing slopes, it is nonetheless representative of pinyon-juniper woodlands in the study area.

The data collected at this site show that pinyon-juniper woodlands are the coldest of the four major vegetation types. This relationship is true of the entire temperature profile. The woodlands, together with upland-sagebrush sites, receive less effective solar radiation at the surface. In woodland sites this low level of insolation results partly from shading by the canopy cover and partly from slope angle. Snow cover during the winter also reduces the amount of radiation absorbed.

Based on these initial analyses, it is apparent that soil moisture and temperature differ substantially among the vegetation types. Additional analyses of data already collected in combination with new data will help to strengthen the definition of these relationships.

(iii) Nutrients

Figure V-51 is a summary of soil characteristics for the major vegetation types on the Tract. This figure shows the relative values for nitrate, phosphorus, calcium, pH, magnesium, potassium, electrical conductivity, zinc, field capacity, boron, copper, iron and manganese for each of the four major vegetation types. Values shown in Figure V-51 have been computed from actual nutrient values using a ratio. The highest value for a given nutrient in one of the stands was set equal to 100 percent, all other values were then adjusted proportionately. Average shrub densities and herbaceous cover for each vegetation type are also listed for reference.

The preliminary analysis of these data has not shown the presence of strong trends between vegetation and soil nutrients (Chapter V). None of the vegetation types has high nutrient regimes; all are deficient in zinc and most are low in phosphorus and potassium. The most revealing features of the nutrient regimes are the differences in woodland and chained woodland sites as a group, and big sagebrush sites as another group. Both the electrical conductivity (total salts) and sulfate are high in the latter group, as is pH. These high values are accompanied by relatively high levels of nitrate, potassium, copper, manganese, magnesium and iron. Since big sagebrush occurs at high densities on sites with these characteristics there is an implied relationship between the tolerance of sagebrush for high salts, low available water and high pH. There may be some interrelationship with trace metal values, but this is not descernible at this time. Based on soil-productivity assessments (Chapter VI) the chained rangelands have the most productive soils of the four vegetation types, this being attributed to more substantial populations of soil microorganisms in this vegetation type. Comparisons indicate that pH is an important factor both in the availability of phosphorus, as well as in its influence on the activity of microorganisms, both of which are promoted by lower pH (ca.7).

The availability of soil nutrients to plants is influenced by microorganisms in the soil, by temperature, soil moisture and pH. Soil pH, on the other hand, may be influenced by vegetation litter which is mixed with soil. Redistribution of salt concentrations is another example of plant influence since certain species of plants absorb substantial quantities of salts and return them to the soil surface through leaf fall.

b. Relationships to Biotic Factors

Four major groups of herbivores interact with vegetation on Tract C-b, including arthropods, small mammals, wild ungulates and domestic livestock. The sequence of discussions below does not imply relative significance of each group, but rather an increasing order of conspicuousness among groups.

(i) Arthropods

Arthropods on the Tract function as herbivores, insectivores and scavengers. Many of these arthropods have evolved complex interactions with various plant species over thousands of years. Within the tree and shrub canopy and on the ground surface some of these interactions proceed unnoticed except during periods of heavy insect infestations. For example, the most common and conspicuous damage to vegetation is probably defoliation (Furniss and Barr, 1975) by a host of defoliators. Other damage may occur to plant roots, stems and reproductive parts.

All of the common shrubs and trees on Tract C-b serve as hosts for a variety of arthropods. Long-horned woodboring beetles, leaf beetles and fruit flies may occasionally infest big sagebrush and cause defoliation, root damage, reduced growth and occasionally death of the plant. Metallic wood-boring beetles, leafhoppers, mountain mahogany leaf notchers and western tent caterpillars are known to attack mountain mahogany with similar effects and with the extent of the damages related to the number of arthropods. Antelope bitterbrush is a host for many arthropods such as metallic wood-boring beetles, stink bugs, measuring worms, tent caterpillars and thrips. The latter are small insects feeding within the flowers and do little harm to the host shrub yet may prevent formation of seeds (Furnish and Barr, 1975). Up to 90 percent of the annual pinyon-pine-cone crop can occasionaly be destroyed by cumulative actions of insects according to studies reported by (Keen, 1958).

Several of these arthropod species occasionally become abundant enough to cause serious destruction and death to large stands of affected shrubs. Hansen and Ueckert, (1970) reported that at densities of seven per square meter grasshoppers have a potential to consume about 400 kg of forage per hectare over a growing season. Densities of this magnitude seldom occur, however, because many of these potentially harmful arthropods are controlled by other insects. Many species of extremely small flies and wasps are parasitic on the eggs, larvae or adults of these herbivorous arthropods and are often species-specific in their parasitism.

Not all arthropods are destructive to the shrubs and herbs they inhabit and many arthropods play a critical role in the success of reproduction by these plants. Many bees, flies and beetles assist in pollination. Arthropods as a group are essential components of ecosystems, providing a food-web base to insectivorous consumers such as shrews, bats, many birds and lizards (Figure VII-4).

Man has become a critical factor in the last few decades in plant-arthropod relationships by the application of pesticides to control certain pest species. The application of pesticides must always be carefully considered since not only the target pest may be killed but also many of the naturally occurring arthropod parasites that control populations of other potentially destructive arthropods.

(ii) Small Mammals

The four most abundant small-mammal species (least chipmunk, deer mouse, montane vole and golden-mantled ground squirrel) are all important consumers of vegetation of Tract C-b; collectively they probably consume little plant biomass relative to that consumed by arthropods. The kind of plant species selected by small mammals varies with species and with season or plant availability. Both the golden-mantled ground squirrel and the montane vole are considered to be grazers or croppers with 90 percent or more of their diet consisting of vegetation (McKeever,1964; and McNab,1963). Voles generally prefer succulent portions of vegetation. Conversely, both the deer mouse and least chipmunk consume significant quantities (up to 80 percent of their diet) of arthropods on Tract C-b (Table V-12) and are generally described as insectivores as well as herbivores (Aldous, 1941; Johnson 1961). Both species tend to concentrate on seeds when seeds are abundant, but diet selection by all these species is modified by availability of food items which is determined primarily by the season and weather. These species are therefore termed opportunistic and subsist on a variety of foods as they become available. Figures VII-8 and VII-9 reflect food habits in two important small mammal habitats, i.e., chained pinyon-juniper rangelands and pinyon-juniper woodlands.

The quantity of vegetation consumed varies with availability, ambient temperature and the activity of individuals in a population. For example, the quantity of herbaceous vegetation consumed is generally greatest in spring and early summer, and the quantity of seeds consumed is generally greatest in late summer and early fall. For species active throughout the year, the relative amount of energy consumed (i.e., consumption of primary productivity) in general is greater during winter since the energy cost of temperature regulation is greater in the winter for homoiothermic animals. Because a homoiotherm expends most of its energy intake for thermoregulation, only about 10-20 percent is available for activity, although this figure varies with body weight (McNab, 1963). Since energy demands, owing to activities such as growth, reproduction, foraging and territorial defense, vary with the level of activity, the consumption of vegetation to support these energy demands also varies.

Based upon studies by Golly (1960), McNab (1963) and Brant (1962) and considering species compostion and densities of small mammals on Tract C-b, it is estimated that total consumption of primary production available to the herbivorous small mammals is in the range of 2-5 percent. This range represents the variability associated with seasonal temperatures and activity discussed above. For example, the percentage consumption of primary productivity may be altered significantly by the seasonal and annual fluctuations in environmental temperatures. In addition to temperature fluctuations, variation in activity levels such as number of litters produced, size of home range utilized in foraging and growth rates all affect the percentage consumption of primary productivity.

Mammals and herbivorous birds function in other ways than simply herbage consumption. They often play an important role in the distribution of certain plant species. Seed dispersal by birds and mammals

NOTE

① Standing crop estimates in kilograms per hectare

② Estimates represent the relative frequency of food items comprising small mammal diets

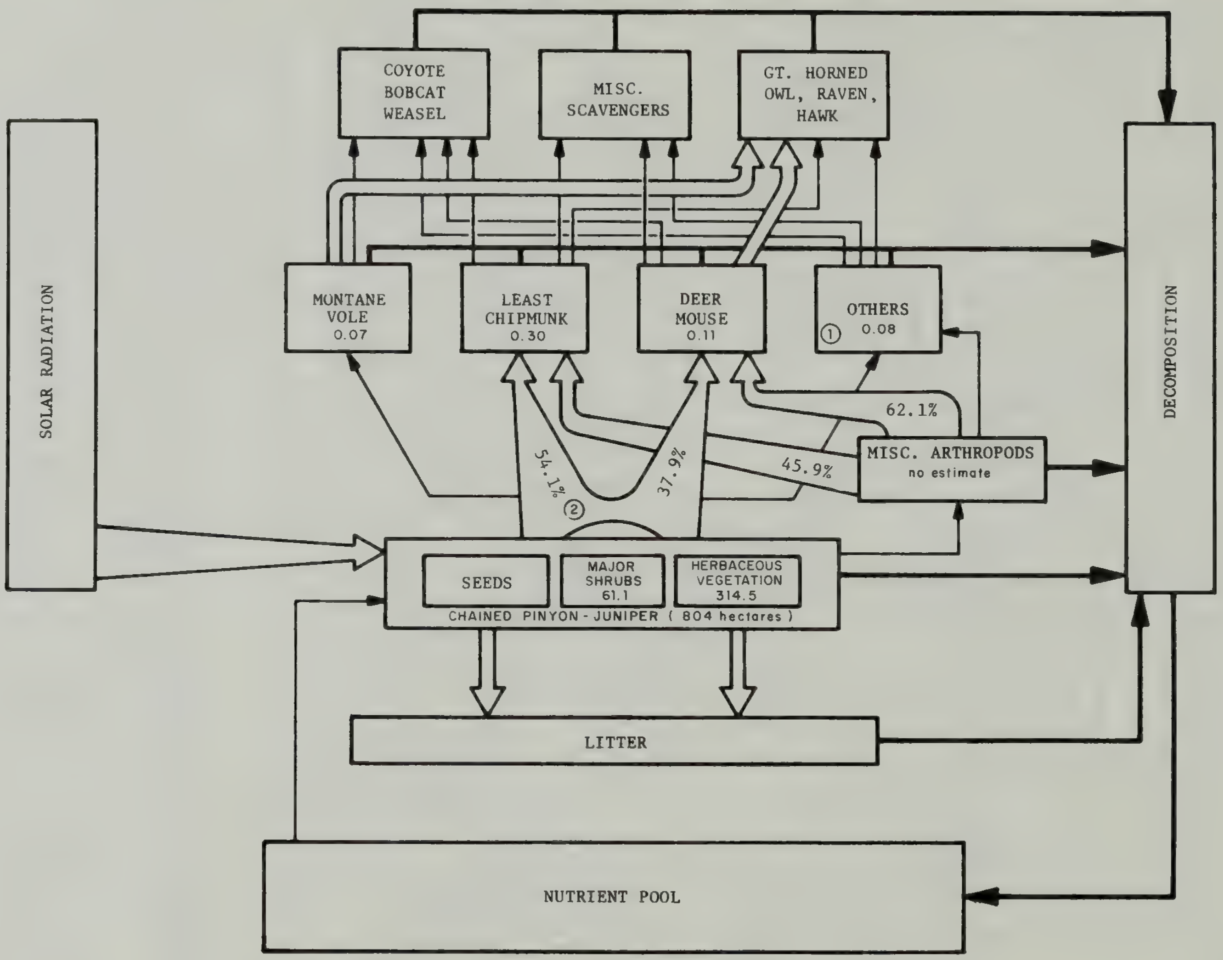


Figure VII-8 Standing crop pathways for small mammal populations in the chained pinyon-juniper habitat type

74-669

NOTE

1 [S]tanding crop estimates in kilograms per hectare

2 Estimates represent the relative frequency of food items comprising small mammal diets.

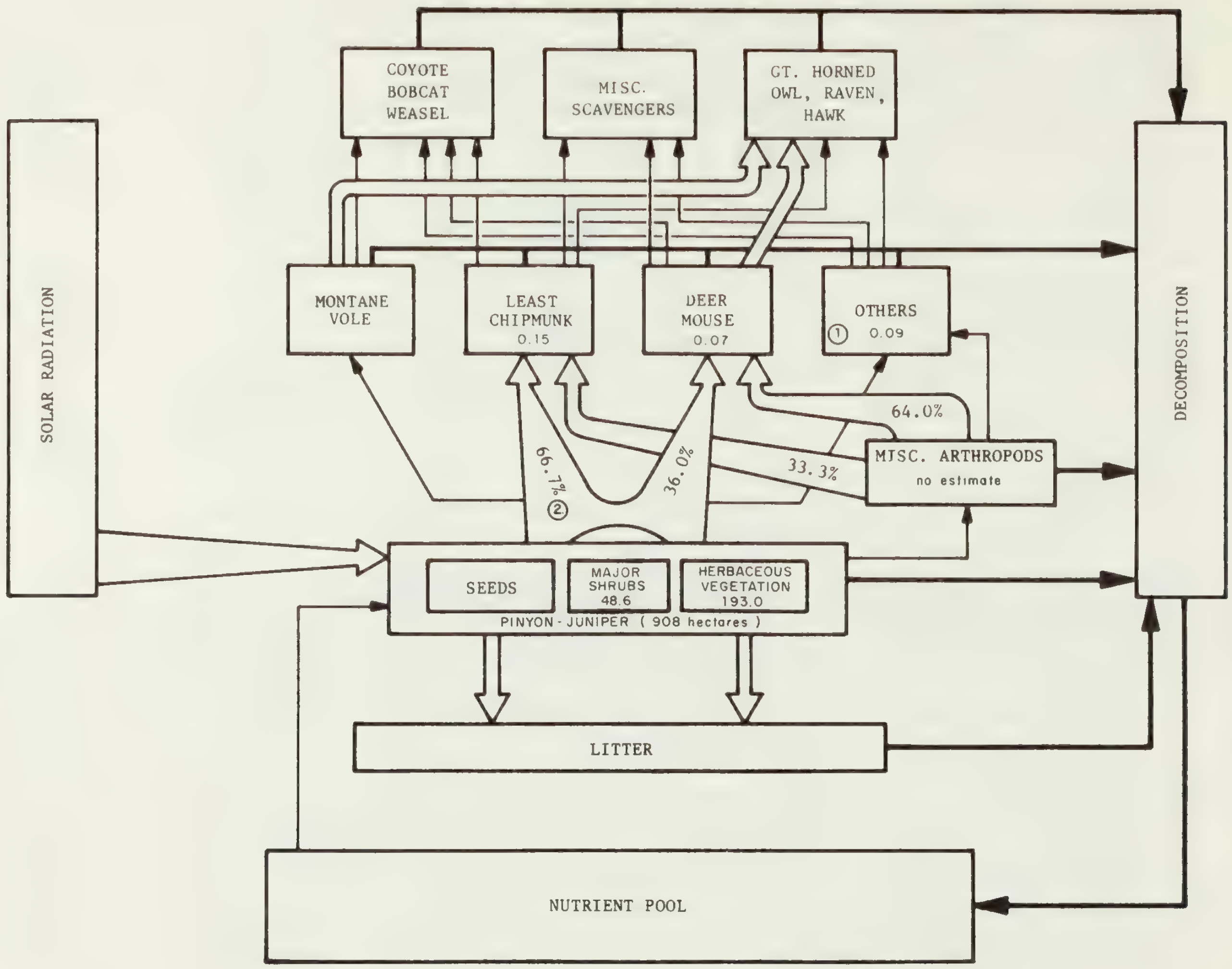


Figure VII-9 Standing crop pathways for small mammal populations in the pinyon-juniper habitat type

is perhaps the most naturalistic effect of animal/plant relationships in pinyon-juniper areas according to Frischkneckt (1975). This probably holds true for sagebrush communities, too. Juniper and pinyon seeds, for example, can be transported long distances in small mammal cheek pouches and feces of birds and mammals. Johnson (1962) gives evidence that seeds of certain species which pass through digestive systems germinate faster and remain viable longer than seeds that have not been ingested. Invasion of certain grassland areas by juniper has been attributed to seed distribution by birds and mammals (Parker, 1945).

(iii) Wild Ungulates

Deer occupy Tract C-b and the surrounding area from about September through May. During the winter deer rely heavily on browse species such as big sagebrush, mountain mahogany, serviceberry and antelope bitterbrush to meet their nutritional requirements. In the late fall and early spring the hay meadows along Piceance and Willow Creeks provide a substantial portion to their diet. Figures VII-10 through VII-13 illustrate major interactions involving mule deer in the four principal vegetative types on the Tract. Rather than showing the energy in each level that is available to the next higher level, the diagram shows numbers, biomass or percentages. The actual energy involved at each level has not been determined.

Data from surveys conducted during the first year of studies (Table V-36) show that total mean annual standing-crop of selected shrub species for the six study areas ranged from 243-6126 lbs/acre. Estimated new year's growth for four major browse species (big sagebrush, antelope bitterbrush, mountain mahogany and serviceberry) ranged from 0.5 to 130.5 lbs/acre. Estimates of utilization for these browse species from the marked shrubs show ranges from 54 percent for big sagebrush in the valley bottoms to slightly less than 75 percent for all species in other vegetation types. Although mule deer feed on a large variety of shrub and herbaceous species (Kufeld et al., 1973), shrub species are important to their overwinter survival on Tract C-b. During severe winters mule deer in the Piceance Creek Basin also consume large quantities of juniper and pinyon pines (Hansen and Dearden, 1975). Consequently, the Tract vicinity is a variety of vegetative communities and produces a wide range of suitable dietary items for deer.

Generally, Tract C-b appears to be heavily utilized by deer during winter. At present, there is no reliable estimate of deer numbers taken by mammalian predators, but it is felt that generally the weakened animals succumb to predation. The number of road kills involving deer wintering on or around Tract C-b is also unknown.

(iv) Cattle

Cattle utilize the Bureau of Land Management (BLM) allotment area (which includes Tract C-b) from April to October. Indirect competition between cattle and deer may exist if cattle utilize forage during summer, thereby limiting its availability to deer during winter. During severe

NOTE

(1) Standing crop estimates in kilograms per hectare.

(2) Estimates represent percent consumption of new shoot production.

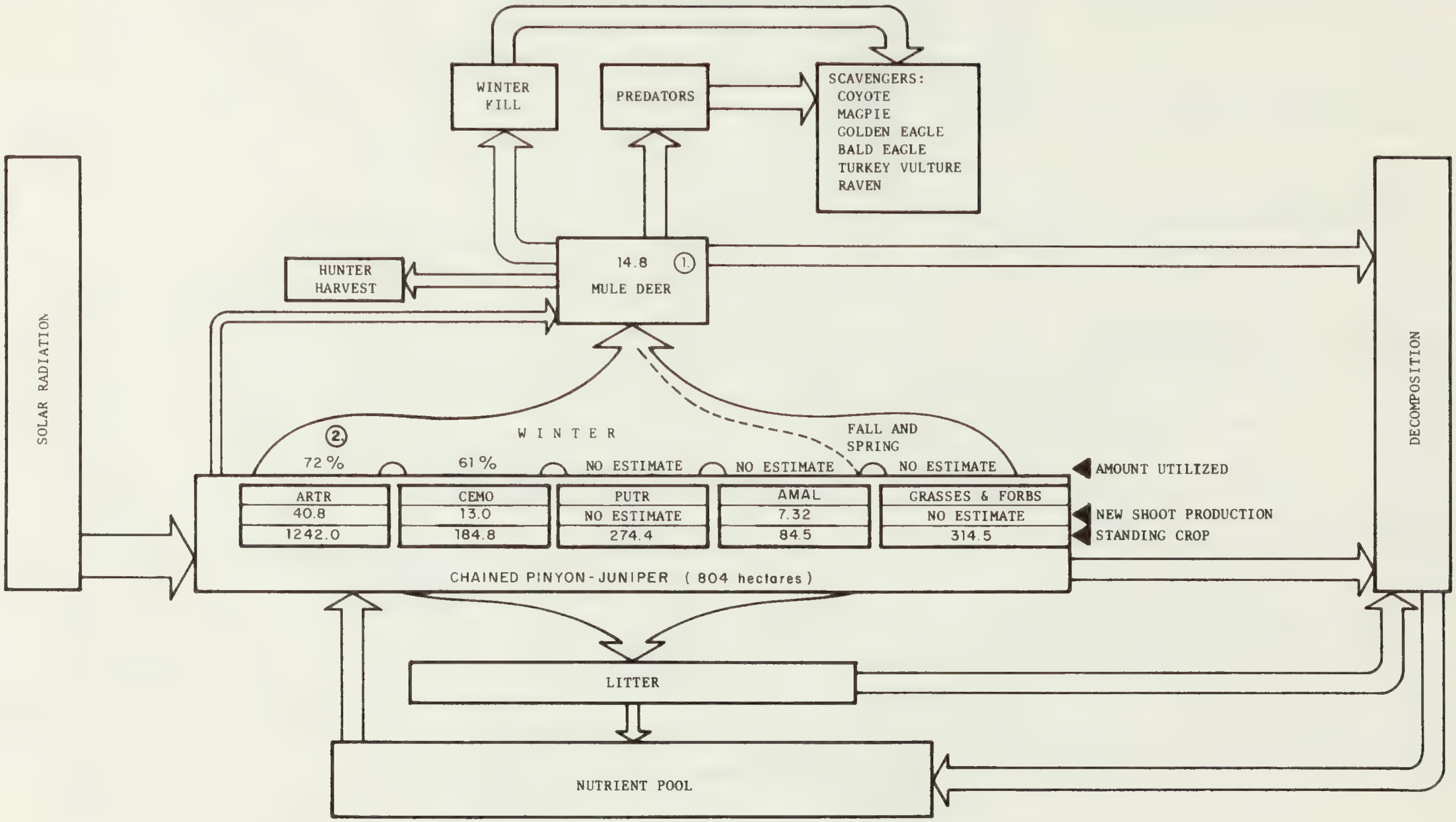


Figure VII-10 Standing crop pathways for mule deer in the chained pinyon-juniper habitat type

74-669

NOTE

(1) Standing crop estimates in kilograms per hectare.

(2) Estimates represent percent consumption of new shoot production.

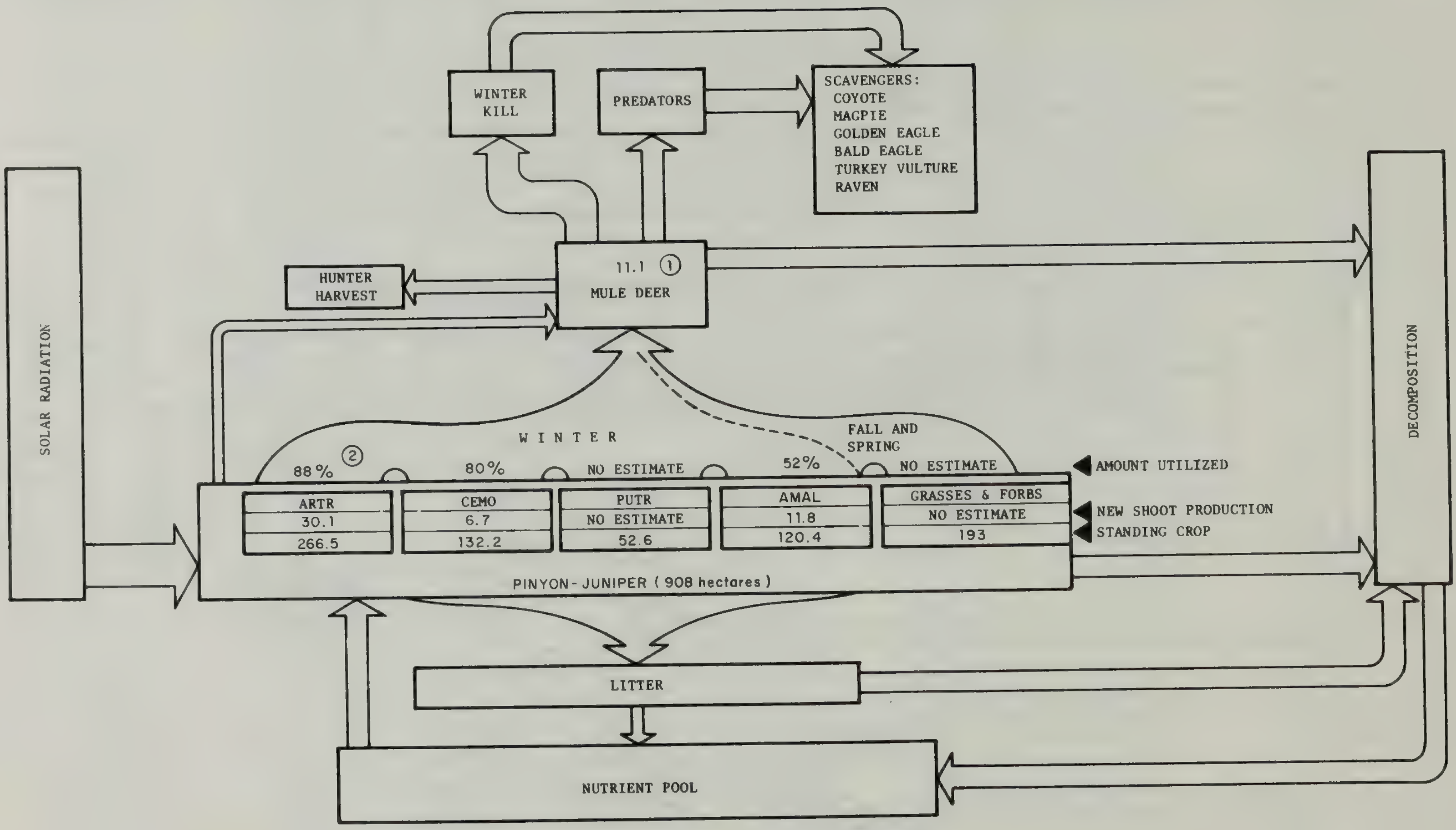


Figure VII-11 Standing crop pathways for mule deer in the pinyon-juniper habitat type

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NOTE

(1) Standing crop estimates in kilograms per hectare.

(2) Estimates represent percent consumption of new shoot production.

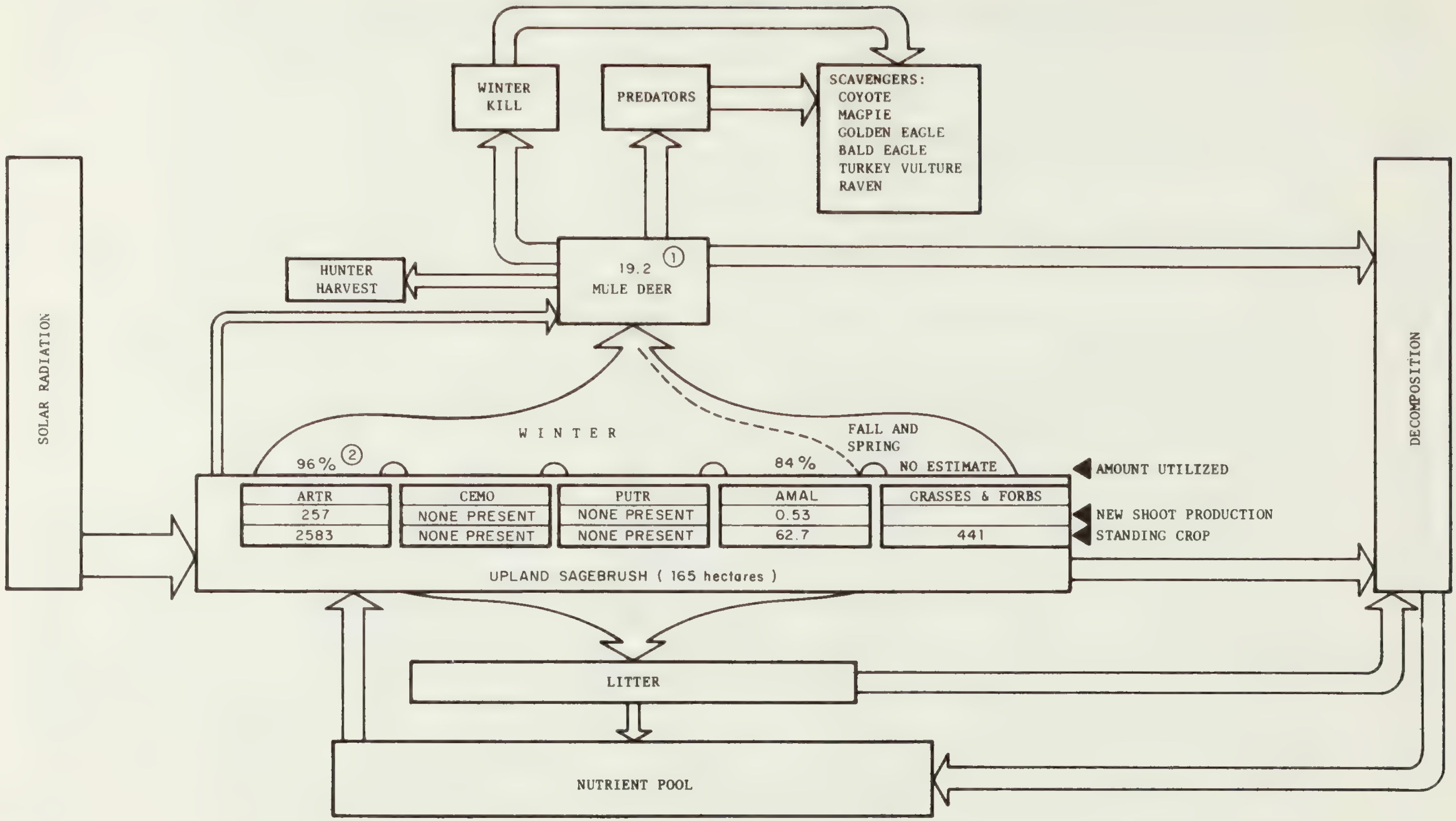

Figure VII-12 Standing crop pathways for mule deer in the upland sagebrush habitat type

74-669

NOTE:

1. Standing crop estimates in kilograms per hectare.
2. Estimates represent percent consumption of new shoot production.

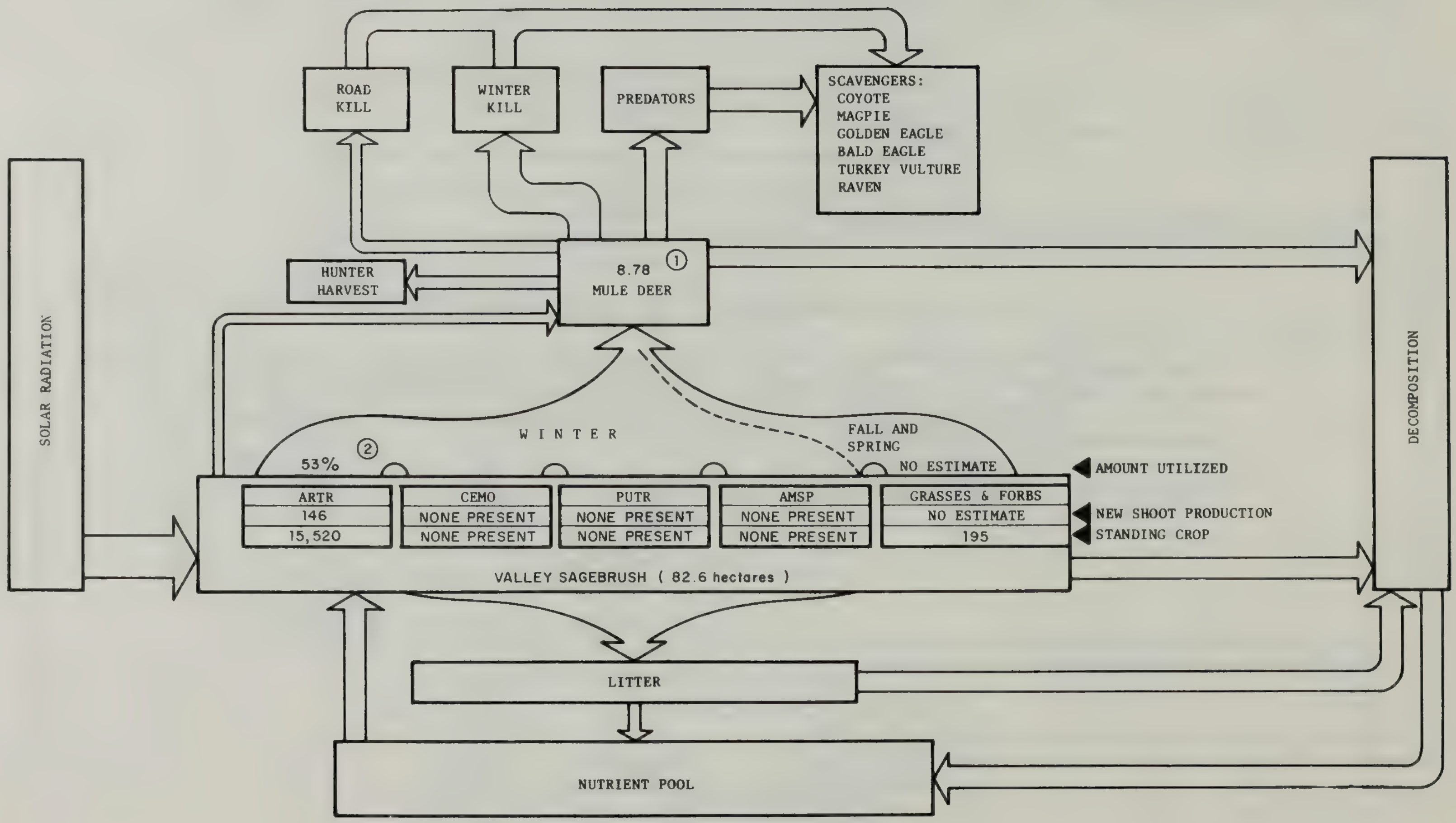

Figure VII-13 Standing crop pathways for mule deer in the bottomland sagebrush habitat type

74-669

winter periods any significant decrease in range carrying capacity caused by cattle grazing or compaction could conceivably result in increased winter deer mortalities because of malnutrition and attendant problems.

The pattern of cattle use on Tract C-b was observed from August 1974 through September 1975, and is summarized here. Cattle do not winter on Tract C-b but are released to graze in nearby hay meadows during early spring. As the growing season progresses, cattle move away from the hay meadows, pass through Tract C-b and eventually summer at higher elevations south of the Tract. At any one time few cattle are grazing on Tract C-b. It appears, therefore, that the Tract is little utilized by cattle during the growing season. Productivity measurements for the herbaceous layer in 1975 support these observations. There appears to be no significant differences in production within cattle exclosures and plots open to grazing at the vegetation study sites. This suggests that no significant overgrazing takes place on Tract C-b during the growing season.

As winter approaches, the cattle descend from their summer range, pass through Tract C-b and utilize the hay meadows north of the Tract extensively. During the movement period a small number of cattle graze on the Tract. During the period from November 1974 through October 1975 few cattle, if any, utilized the Tract. From one year's observations it appears that deer utilize Tract C-b heavily from October to May; cattle utilize the Tract very lightly in the spring and fall, and are virtually absent in June, July and August. During the fall, however, heavy utilization of hay meadows along Piceance and Willow Creeks occurs by both deer and cattle. Both herbivores graze on the stubble in the fields. At this time deer also begin to browse the preferred shrubs on the Tract, while cattle continue to graze extensively all vegetation in the valley bottoms.

Some range ecologists, among them West et al. (1975), believe that past introduction of cattle into the region characterized by pinyon-juniper communities has markedly affected ecological structure and processes. These authors conclude that grazing has led to an expansion of the original range of the pinyon-juniper vegetation type. They report that with onset of cattle grazing pinyon and juniper trees invaded what was formerly savannah, grassland or shrub-steppe communities. Concurrent with the invasion of new areas was a substantial increase in tree density within extant stands. In some areas the trees have replaced formerly abundant shrub and herbaceous understory. Terrestrial vegetation studies (including dendroclimatological studies) indicate that this is not the case in the pinyon-juniper woodlands in the Tract C-b area (see plant succession).

(v) Plant Succession - Tract C-b

Plant succession is the orderly replacement of one plant community by another over time. Major changes in plant communities brought on by

climatic shifts or changes resulting from evolution of new species in a geologic time frame are not considered as successional changes. The existing vegetation in the Piceance Basin is composed of many plant communities which have developed in response to a multitude of abiotic factors as well as biotic influences including inter- and intra-specific competition. In the overall pattern of plant communities there is only a limited suggestion of successional changes occurring within the native vegetation types. Co-dominance by both Douglas-fir and aspen on north-facing slopes at higher elevations in the Basin suggest competitive effects and also the successional nature of aspen at least in some portions of the basin.

In the Tract C-b area the vegetational mosaic appears to be composed of stable communities except on those sites where the vegetation has been disturbed by human activities and also in those limited areas where the pinyon-juniper woodlands have been burned. The successional changes within the area are occurring on these disturbed sites (old burns, chained areas, sites disturbed by road construction and areas sprayed with herbicide). Long-term grazing on the site has also apparently produced some changes in the original vegetation. These changes appear to be limited to structural changes in the affected communities and only in those areas where agricultural activities other than grazing have been employed (formation of meadows and bottomland pastures) do long-term vegetation changes appear. Even though most of the communities are not undergoing successional changes, it must be emphasized that they are not static. Yearly changes occur as the processes of growth, reproduction, death and germination alter the internal structural character of the community. The net result is a stable community which has the same general physiognomic appearance year after year, even though subtle changes continually occur.

On Tract C-b initiation of secondary succession in pinyon-juniper woodlands can be brought about by five major types of disturbances (Figure VII-14). Tree canopy fires, chaining and vegetation removal as part of construction-development activities are the most severe disturbance types because all structural levels of the plant community (herbs, shrubs and trees) are affected by these events. Immediately following disturbances of these types, the condition of the vegetation is similar. Following construction activities, which involve the removal of vegetation, most of the underground plant parts (root systems and rhizomes) have been destroyed. However, depending on the depth of disturbance, a few deeply rooted species may remain. The first plant communities which develop on these sites after 1-2 years are dominated by annual-weed species (Russian thistle, pigweed, flaxweed, tumble mustard, amaranth and others). These species are adapted to the extremes in abiotic factors which characterize the disturbed sites. The weed communities may persist for 10-15 years but during this time an increase in perennial grasses and forbs may be noted. Along with the perennial herbs seedlings of pinyon, juniper and shrub species eventually become established. As they grow and develop the site takes on the appearance of

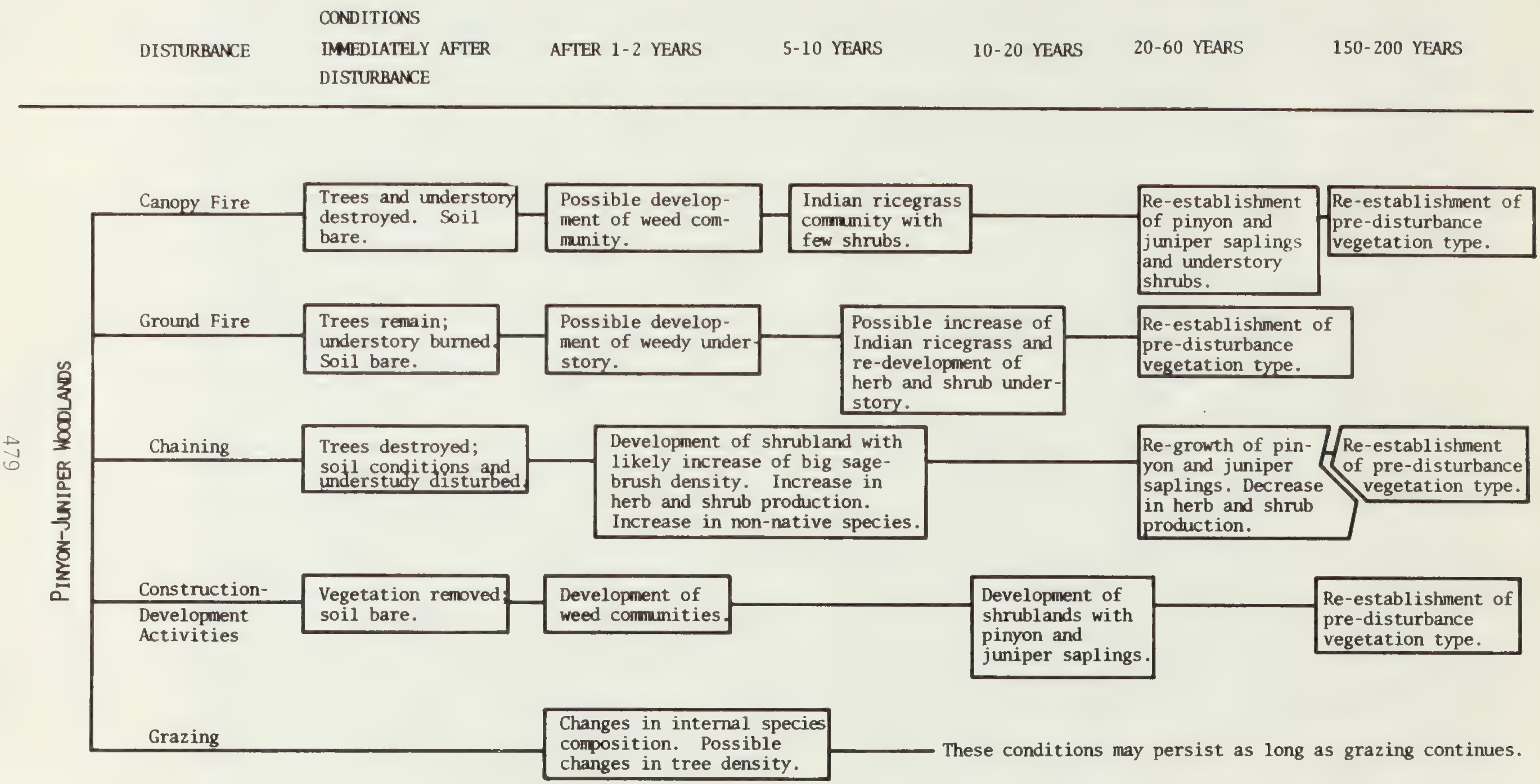

Figure VII-14 Generalized scheme of successional changes following disturbances in pinyon-juniper woodlands in the Tract C-b study area.

a shrubland. Big sagebrush may occur as one of the dominant species during this successional stage. The eventual re-establishment of a mature woodland comparable to that which existed prior to disturbance may require 200 years or longer. Since soil conditions are greatly modified by construction activities, re-establishment of original vegetation requires a longer time than for other disturbance types.

Tree canopy fires are the most destructive natural events which occur within the study area and cause the removal of all (or nearly all) of the above-ground vegetation. Since the vegetation is removed, the soil surface is exposed and is subject to increased surface runoff. Nutrients, which have been tied up in woody plant biomass, are released into the system as a result of fires and thereby increase soil nutrient levels. Post-fire conditions vary from site to site and the first communities which develop may be different for each site. Weedy species may be the first to colonize the burned areas; however, within the Tract study area the burned sites appear to be quickly dominated by Indian ricegrass, so that by 5-10 years after a fire this perennial grass may be the most abundant species. Eventual establishment of shrubs and tree saplings causes a decrease in grass coverage, and after 150-200 years a mature woodland will become established. Since fires usually do not destroy established root systems (some species, however, are not fire tolerant and the loss of above ground tissues causes the death of the entire plant) or significantly disturb soil conditions, the time necessary for recovery is less than in situations where surfaces are cleared for construction activities.

Chaining initiates secondary succession by removing the tree layer. Disturbances are also caused in the herb and shrub layers through the mechanical actions of the chaining process. However, the process tends not to destroy the herbs and shrubs and thereby produces a situation in which secondary woodland succession has a head start when compared with canopy fires or construction disturbances. The presence of developed shrub and herb layers as well as the occurrence of tree saplings accelerates the rate of succession in chained areas. Immediately after chaining sites are characterized by the felled trees and disturbed soil conditions. Soil disturbances favor the increase of weed species, especially cheatgrass, which grows very well in this portion of the state. The removal of the tree canopy increases the amount of solar radiation in the herb and shrub layers and increases the proportion of moisture and nutrients available to herbs and shrubs as a result of the removal of tree competition. Several years after chaining an increase in herb and shrub production can be noted and the physiognomic appearance of the vegetation is that of an open shrubland. Since the tree saplings are not removed by the chaining process, the vegetation takes on the appearance of a young woodland within 30-50 years as the saplings develop into small trees. Increased competition with these trees results in decreases in herb and shrub production. Woodlands comparable to prechaining communities would require approximately 150 years to reach maturity. This time scale is in general agreement with the findings of other workers (Frischknecht, 1975).

Ground fires in the woodlands have effects nearly the inverse of those caused by chaining since ground fires tend to remove the herb and shrub layers and leave the trees standing. Succession in this case is limited to the re-development of these structural layers. Since trees remain, root systems remain intact and soil conditions are not substantially altered, recovery from ground fires is much more rapid than in instances of canopy fires. Weedy species may invade the forest understory; however, in the C-b area Indian ricegrass appears to be the primary early-colonizing species. Eventual re-establishment of shrub and herb species probably occurs within 20 years and conditions comparable to pre-fire communities are likely reached within 50 years.

In the Tract C-b study area livestock grazing appears to have had little effect on the pinyon-juniper woodlands and has apparently not altered the successional status of the woodland communities. Grazing-related disturbances cause changes in herb-layer species composition and can alter structural characteristics within the woodland understory. Expansion of the woodlands into other upland vegetation types as a result of livestock grazing has not apparently occurred within the area. Dendrochronological data suggest long-term dominance by pinyon pine in the study area (See Section V-D). Recent studies in Utah (Dwyer, 1975; and West et al., 1975) seem to indicate that in these regimes pinyon-juniper woodlands were once more open and savannah-like. Grazing disturbances are offered as explanations for increased tree densities. This does not appear to be the case in the Tract C-b study area. One possible explanation for this difference is the greater elevation and annual precipitation at C-b. Increases in herb and shrub standing crop would probably be noted subsequent to the removal of livestock grazing. Introduced weedy species associated with agricultural activities are now a permanent feature of the native woodlands and these species are likely to persist even if livestock grazing influences were eliminated.

Disturbances in upland-sagebrush communities (Figure VII-15) are the same as those which initiate successional changes in the pinyon-juniper woodlands. In general re-establishment of shrub communities requires less time than that necessary for development of woodland vegetation. Based on growth-ring counts for mature sagebrush plants in upland communities, 50-75 years may be required for re-establishment of mature upland-sagebrush communities in the absence of management. Disturbances from construction activities produce conditions of bare compacted soil and complete removal of vegetation. Recovery from this type of disturbance would take longer than the time required for recovery from other types of disturbance. The first plant community which develops on these sites is composed primarily of annual weeds; however, a few deeply rooted perennial herbs may still grow on the site if the soil disturbances have been shallow (six inches or less). The weed communities eventually contain greater percentages of perennial plants and shrubs as these species become re-established. The first shrub species to become established are also those which assume dominance in the final equilibrium-state community which eventually develops. Individual big-sagebrush plants may become established after 10 years and a mature, sagebrush-shrub community should develop within 50-75 years.

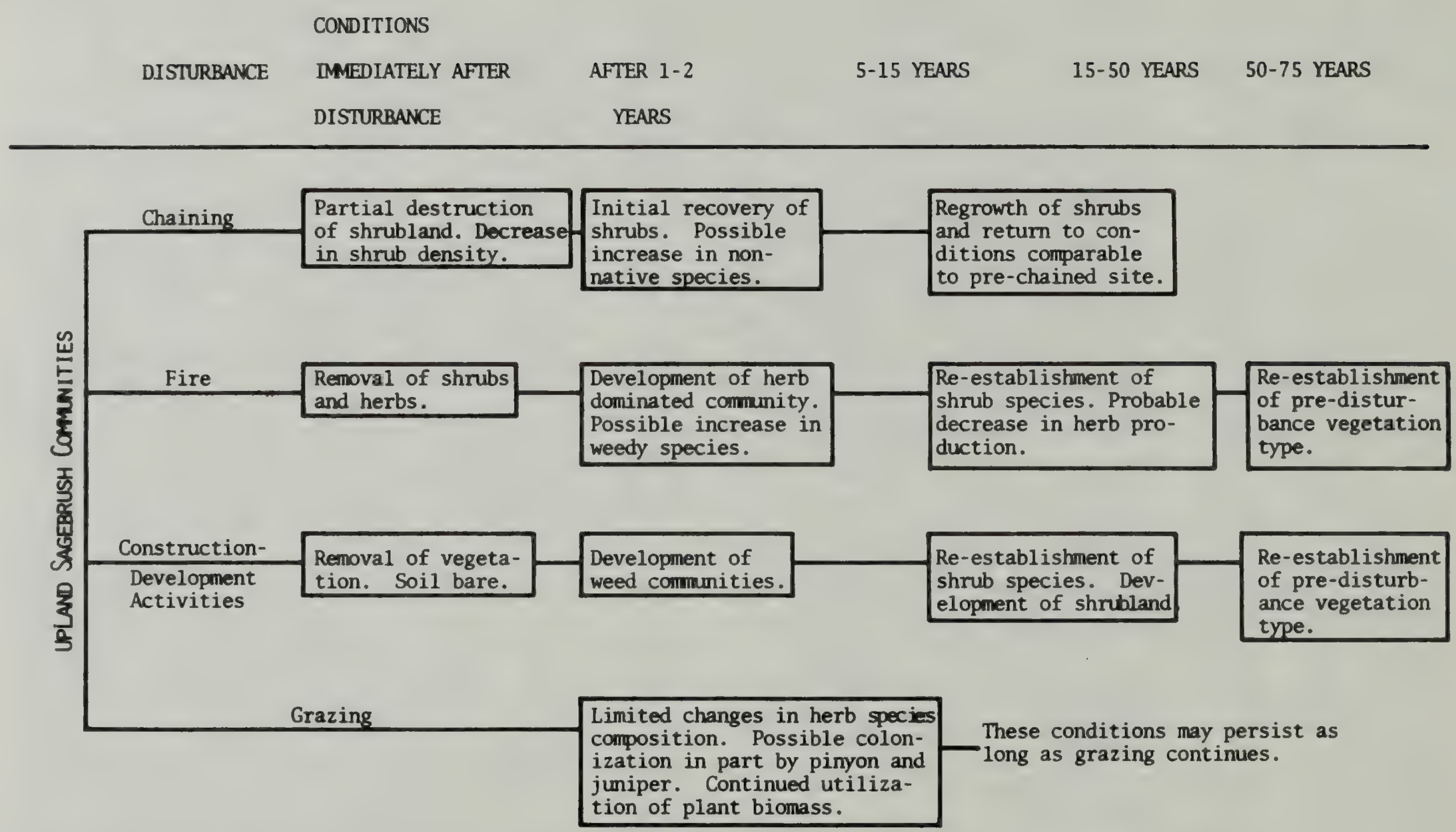

Figure VII-15 Generalized scheme of successional changes following disturbances in upland sagebrush communities in the Tract C-b study area.

Fires occur only occasionally in the upland-shrub communities. Successional changes following fire would most likely include development of an herb-dominated community followed by eventual re-establishment of the shrub species. Recovery of upland-sagebrush communities after fire may take as long as 50-75 years.

Incidental chaining of sagebrush clearings apparently occurred when much of the Tract woodlands were felled in the late 1960's. Chaining appears to have had little effect on the upland-sagebrush communities and recovery appears to have been complete within less than 10 years' time.

Grazing of upland-sagebrush sites appears to have had little effect on the vegetation. The presence of introduced annual weedy species suggests that grazing has caused limited changes in herb-layer species composition. There is also limited suggestion of extension of pinyon and juniper saplings into the upland-sagebrush communities. Only a few individual saplings occur in the sagebrush clearings and they probably represent an occasional event in which a seedling becomes established in the sagebrush-dominated community. Grazing disturbances may enhance the liklihood of this event. If livestock grazing influences were removed, there would probably not be substantial changes in upland-sagebrush communities.

Secondary succession in the bottomland-sagebrush communities has been initiated by construction activities, herbicide spraying and grazing-agricultural activities (Figure VII-16). Successional changes after construction activities in the bottomland communities follow the same pattern of development of weed communities and eventual re-establishment of shrub species in the absence of management techniques. In these bottomland communities big sagebrush is the dominant species; however, it appears that at least 5-10 years are required for its re-establishment on disturbed sites. Development of mature stands of sagebrush may require 60-80 years based on stem growth-ring counts from mature individuals.

Herbicide spraying has been used as a management technique by the Bureau of Land Management in the bottomland-sagebrush communities. The spraying effectively reduces crown cover by woody and broad-leaved herbaceous plants, however, complete destruction of the shrub layer usually does not occur. Following spraying, an increase in grass production may be noted. Recovery of perennial herbs and shrubs begins after 2-3 years and after 10-15 years a substantial shrub component may have developed. Rubber rabbitbrush and big sagebrush both recover after spraying; however, observations in sprayed areas suggest that rubber rabbitbrush may recover more quickly than sagebrush. The rabbitbrush appears to compete effectively with sagebrush and may continue as a community dominant for many years.

Grazing and agricultural activities have been more intense in the bottomland areas than they have been in the native upland-vegetation types. Livestock grazing in the dry washes where big sagebrush is the dominant plant species has had little effect on the vegetation. The

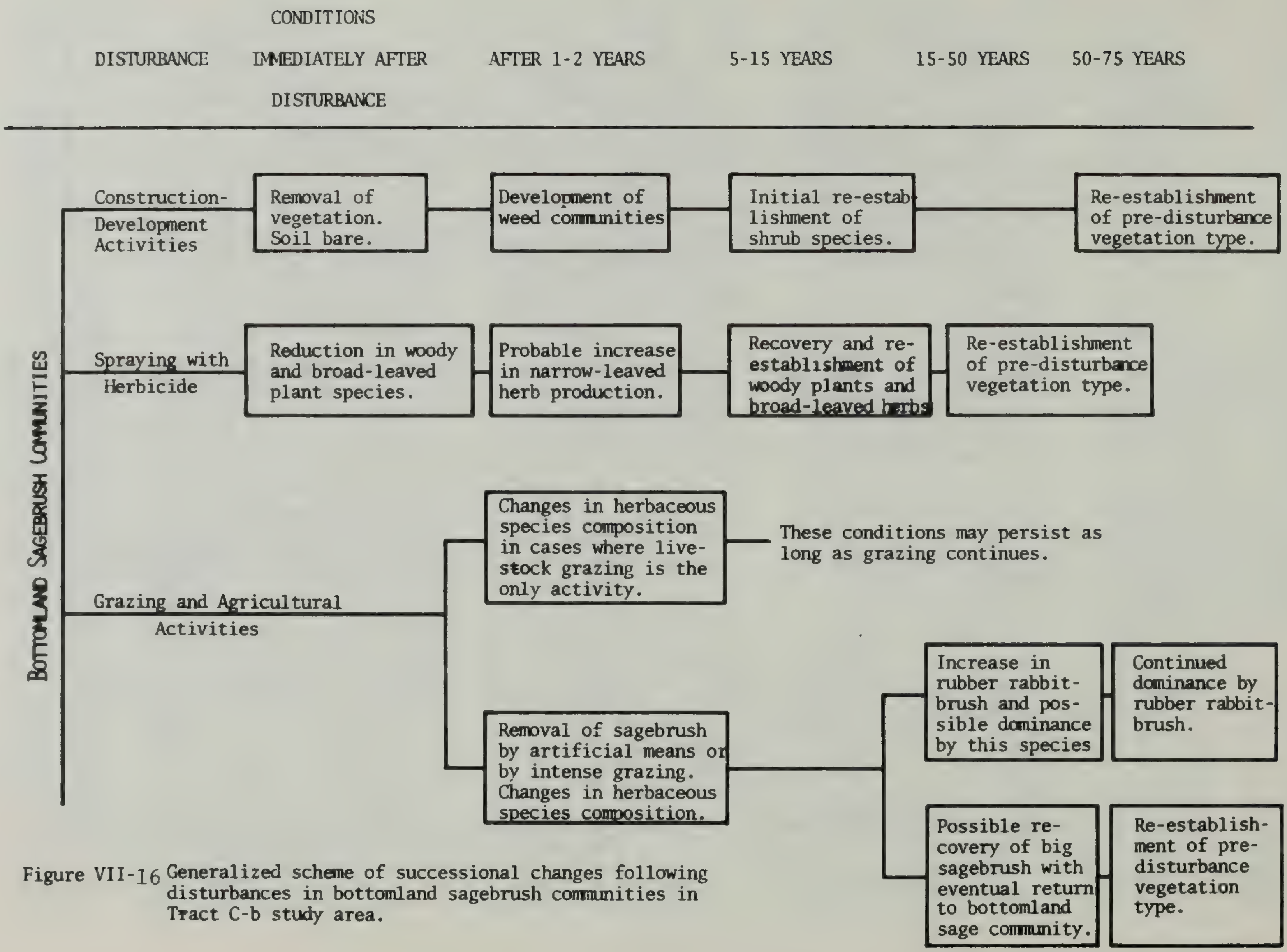

Figure VII-16 Generalized scheme of successional changes following disturbances in bottomland sagebrush communities in Tract C-b study area.

primary effect has been the introduction of weedy species which comprise the major component of the herb layer. If grazing were removed from these areas, little change in the existing vegetation would likely be noted.

In bottomland areas where pastures and hay meadows have been created, there has been considerable alteration of the native communities by local ranchers. In those areas where big sagebrush has been removed, successional changes have apparently produced communities dominated by rubber rabbitbrush. It is possible that these rabbitbrush communities may persist, otherwise big sagebrush may eventually return as a dominant species.

Successional changes following construction activities within other plant communities follow the same general pattern as outlined for the major plant communities discussed above. After a period of dominance by weedy species, native species eventually become established and the pre-development community is re-established.

In general the vegetation pattern within the C-b area, excluding those areas disturbed by human activities, is made up of communities which have characterized the region for the past 500 years. The dendrochronological data indicate the presence of long-term dominance by pinyon-juniper woodlands for at least this long. The first written accounts found in the original land survey records (ca. 1870-1880) of the regional vegetation make mention of plant communities which currently occur in the area.

The successional changes which are now in evidence within the study area have been brought on mostly by the activities of local residents and by governmental agencies.

2. Animal-Environment Relationships

a. Relationships to Abiotic Factors

Although animals respond to both abiotic and biotic elements of their environment, their proximate habitat selection responses are governed principally by characteristics of their biotic surroundings. Vegetative physiognomy (gross structure) has been demonstrated as particularly influential in determining distributional patterns of birds and mammals, for example (Hilden, 1965; Rosenzweig and Winakur, 1969). As a consequence, patterns of animal distribution in most instances are associated closely with vegetative patterning and are much less responsive to abiotic phenomena per se, except as such phenomena dictate vegetational development. Clearly, abiotic catastrophies such as storms, floods and earth slides can markedly affect animal populations and alter distribution patterns until biotic recolonization occurs. A few examples of other responses of animal taxa to abiotic factors are illustrated below.

(i) Terrestrial invertebrates

Although many arthropod taxa are obligates of certain plant species and hence are distributed in the same pattern as the host plant, these

terrestrial invertebrates nonetheless show very clear responses to abiotic factors. Examples were illustrated by the classic work on grasshopper and thrip populations by Andrewartha and Birch (1953) and by many applied entomologists since that time. Insect anatomy and life history are especially well suited to cope with the problems inherent in semiarid environments such as in the Piceance Creek Basin. Although some taxa have narrow tolerances to physical parameters, and hence are restricted to isolated habitats, many groups exhibit wide tolerance limits or have morphological, physiological or behavioral adaptations to the physical extremes such as those present in the Tract C-b area.

Collections in the general Tract region demonstrate the presence of at least five groups which are both important in the ecology of their respective biotic communities and demonstrate marked response to abiotic factors. Harvestmen and scorpions, for example, have narrow ranges of heat and moisture requirements which restrict their overall distribution on and near the Tract. Harvestmen are limited to relatively moist environments where free water is available at least every few days. This situation exists primarily in valley-sagebrush stands and along Piceance and Willow Creeks. Conversely, scorpions prefer more xeric conditions and their distribution is limited to rocky outcroppings and south-slope, pinyon-juniper stands.

Ants, a very important insect taxon in all Tract habitats, react to temperature extremes through site selection and behavioral changes. Different ant species tend to exhibit habitat preferences based on soil texture and soil temperature. Within a habitat ants demonstrate several means of avoiding the effects of extremes in daytime temperatures. Visual observations indicated that several species captured in pinyon-juniper stands on southern aspects were not active during the hotter portions of the day, confining their foraging activities to early morning and evening periods. Within the nest larvae and pupae are transported vertically in response to changes in soil temperature to provide the optimum temperature for development, a clear behavioral adaptation to diurnally changing abiotic conditions. Such behavior was frequently observed in a variety of ant species. Individuals of one species (Eciton) found in the Tract area move the nest from a south-facing slope to a north-facing slope each summer to avoid extremes in heat. As day temperatures decline late in the summer, the nest is transported back to the southern exposure.

Perhaps the two groups in the region which best exemplify the dependence of insects on the correct range of physical conditions are mites and springtails. Mites are abundant throughout the Tract region; and, based on collection efforts it is apparent that their numbers increased as the summer progressed. Most of the mites captured were hard-bodied orbatids, a group whose tolerance of desiccation and extremes in heat is well documented. These mites commence reproduction in June, but due to relatively low soil-temperatures at that time exhibit low population recruitment; under the warm soil regimes of July and through September they increased substantially in numbers.

By contrast, collembola are very sensitive to loss of moisture and compensate for reduced moisture during summer by declining in numbers or by seeking out protected, moist micro-habitats. During June, collembola were present in large numbers on the ground surface in a pinyon-juniper woodland vegetation on a south-facing slope. Collections occurred at night when the humidity was relatively high thereby allowing feeding on surface materials by collembolans. During July, when conditions were dry, collembola were not collected on the surface but were abundant in litter samples. This is an indication that insufficient moisture was available to support surface activity limiting collembola distribution to litter depths where moisture was retained. By September collembola were not present on the surface or in the litter, indicating that adequate moisture was unavailable in any portion of the habitat near the ground surface. This resulted in substantial reductions in numbers and a retreat to depths or to better protected microhabitats such as buried wood and rocks. In the pinyon-juniper woodland on a northern aspect seasonal trends in collembola numbers further substantiated that moisture influences distribution and abundance of this group. June collections showed nearly identical populations to those found in southern-slope, pinyon-juniper habitat; during July, collembola were still present on the soil surface as well as in the litter. Their presence on the surface in July is a consequence of continued moisture availability in northern-aspect habitats relative to the drier conditions on south-facing slopes. During September collembola were still present on the northern aspect although they were confined to the litter.

(ii) Small mammals

Although vegetative structure and food availability are generally of paramount importance in influencing small mammal distribution, a number of abiotic factors importantly affect activity periods and distribution of certain species. Miller's (1964) work in Colorado on pocket gophers, for instance, demonstrated species-specific preferences for soil-texture type. In general distribution of burrowing mammals will be restricted to those areas having appropriate soil depth and texture, irrespective of availability of satisfactory vegetation in other localities. O'Farrell, et al. (1975) have demonstrated the important influence soil temperature has on emergence patterns of hibernating/torpid small mammals and the influence of high,summer,ambient air-temperatures on stimulating small rodents to seek cooler underground refugia. Photoperiod may influence emergence patterns of hibernating mammals (Kenagy, 1973).

(iii) Mule deer

The discussion in Chapter V of deer movements illustrates heavy seasonal reliance of mule deer on portions of the Tract and on the agricultural meadows and adjacent south-facing slopes north of the Tract. Heavy snow accumulation during certain winters or portions of winters, combined with drifting and surface crusting over large areas, tend to concentrate deer on the limited, less favorable habitats on south-facing slopes above Piceance Creek valley; rapid snow melt on these slopes exposes browse.

b. Relationships to Biotic Factors

Producer-herbivore and herbivore-herbivore interactions were addressed in part 1b of this section and will not be elaborated on here. Other types of relationships between biotic elements of the Tract C-b terrestrial ecosystem include animal-parasite, animal-host interactions and predator-prey relationships. Examples related to the Tract vicinity are briefly developed here.

(i) Parasite-mammalian-host relationships

The major ecotoparasites of small mammal species on Tract C-b are lice, mites, ticks and fleas. The latter two groups are of greater interest because of their abundance and because of their disease transmission potential. Ticks have been implicated in the transmission of a number of diseases in the Western states. Dermacentor andersoni, a hard-bodied tick, is a known vector of Rocky Mountain Spotted Fever and Colorado Tick Fever and is abundant on the Tract. A number of fleas are also known vectors of plague in the West. One of these species, Diamanus montanus, has been identified from ground squirrels in the area.

These ectoparasites supply their nutritional requirements by taking blood meals from their hosts. Adult ticks become active in early spring and begin searching for hosts. While on a host, adults copulate and subsequently drop to the ground. Females lay their eggs in litter; when the larvae emerge they actively seek hosts. The adult Rocky-Mountain-spotted-fever tick is usually found on larger mammals such as porcupine, deer and hares while the immature stages find intermediate hosts such as deer mice, ground squirrels and woodrats.

All three life-history stages (adult, nymph and larva) were found on the Tract from about April through October. The adults experience their population peak in the early spring and larval stages reach peak numbers later. The larvae can be quite numerous at times and may have two peaks in activity and numbers. Nymphs usually reach highest numbers by late summer. All stages require a blood meal to metamorphose to the next stage (larva to nymph or nymph to adult) or to successfully reproduce (adult females). When winter approaches,these ticks hibernate and recommence their activity the following spring.

Fleas are common on most small mammals on Tract C-b and are known vectors of plague. Plague is an infectious disease caused by Pasturella pestis, a bacterium. Usually, sylvatic plague (the name given the disease in rodents) persists in low incidences in rodent population, but occasionally humans contract plague when rodent fleas carrying Pasturella contact humans.

Fleas lay their eggs in the nests of hosts where the larvae hatch, feed on organic material, pupate and subsequently hatch into the adult form. Adults spend their time on the host but occasionally leave the host for short periods while the host is on the nest.

Although lice and mites are also known vectors of diseases, their importance to any potential disease transmission in and around Tract C-b is probably not significant. Mites have been implicated with the transmission of encephalitis virus and lice with some typhus fevers.

(ii) Predator-Prey Relationships

Research on small mammal demography is demonstrating very clearly that certain, small mammal species experience dramatic changes in population abundance. Microtine populations are especially noted for their cyclic patterns of abundance, varying from less than one individual/ha at population lows to almost 500 individuals/ha during periods of highest population abundance (Pearson, 1966; Pitelka, 1973). Population changes are often abrupt. Voles can increase in numbers at a rate of 23 percent per week and declines in population numbers of 54 percent per week have been measured (Krebs et al., 1969); peak vole densities generally recur at intervals of two to four years.

Some researchers contend that the abrupt declines are a consequence of extrinsic agents such as food supplies, which become limiting, disease or predators; others consider agents intrinsic to populations and individuals, such as increased agression and stress when populations are dense, are responsible (Krebs et al., 1973). It is probable that both intrinsic and extrinsic mechanisms are operative. Despite incomplete understandings of the fundamental nature of predator-prey interactions, cyclic rises and declines in prey population densities undoubtedly affect avian-and mammalian-predator numbers (Pitelka et al., 1955; Pearson, 1966) and predators are known to exert marked influence on prey numbers during at least portions of the cycle (Pearson, 1966; Fitzgerald, 1972; MacLean et al., 1974). Similar interactions between insect (prey) abundance and insectivorous mammals, birds, reptiles and amphibians also occur but in these cases the relative roles of control are generally less well understood than in instances where small mammals serve as prey.

In view of the above,cognizance of principal predator-prey relationships is essential to an understanding of ecosystem function in a particular locality.

On Tract C-b, the most common non-insect predator and prey species identified to date are listed below. Magpies and turkey vultures are primarily scavengers and are discussed separately.

<u>Prey Species</u>	<u>Predators</u>
Desert cottontail	Coyote
Least chipmunk	Bobcat
Golden-mantled ground squirrel	Weasel
Deer mouse	Badger
Montane vole	Raccoon
Long-tailed vole	Striped skunk
Northern pocket gopher	Red-tailed hawk
Busy-tailed woodrat	Roughlegged hawk
	Marsh hawk
	Golden eagle
	American kestrel
	Great horned owl
	Raven

In the Tract area the principal vertebrate predators and their most common prey have been identified; data on preferred habitats and general level of abundance over the year are also being obtained. Because of the relative ease with which raptor pellets (regurgitated casts of identifiable bones and hair) can be collected and examined, some quantification has also been achieved regarding raptorial food habits. Otherwise, interpretations are based largely on field observations.

In terms of ecosystem functioning, predator-prey interactions involve population effects on both the predator and the prey. One question of importance to understanding ecosystem interrelationships concerns the magnitude to which a prey population is suppressed by predation and whether predation is an important agent in controlling population levels of the prey. A second question focuses on population responses of predators to fluctuations in prey density and response-time lags. Site-specific answers to either question require evaluation of data on both predator and prey populations and an analysis of dietary preferences over a period of years. At this time such data are not available for the Piceance Creek Basin but generalizations are still possible. One generalization which emerges from long-term studies is that some predator populations show numerical responses to marked changes in prey density (cf. Pitelka et al., 1955). During periods of prey population eruption, numbers of nesting pairs, nesting success and average brood size of certain raptors dependent on the prey usually increase; predator populations generally achieve peak numbers about the time prey populations decline. As described earlier, population declines of prey species are often precipitous. Such "crashes" result in an immediate overabundance of predators relative to their food base, thereby accounting for periodic dispersal of predators. To date no evidence of such dispersals away from the Tract region has been observed, yet investigations over a period of years would probably demonstrate occasional occurrences of such a phenomenon.

Even though interdependencies of predatory-prey population dynamics have not been exhibited on the Tract during the relatively short period of field investigations, their occurrence in areas far removed from Tract C-b are nonetheless affecting the Tract's terrestrial ecosystem. For example, the principal wintering raptor on the Tract during 1974-75, the rough-legged hawk, breeds on the arctic tundra. In the tundra it is heavily dependent upon small rodents for food. These rodents undergo abrupt population increases and declines on an average cycle of about four years. During prey population increases rough-legged hawks undoubtedly show numerical increases. Because arctic prey populations usually achieve peak densities about every fourth year, rough-legged hawks also should achieve highest population numbers near or soon after the time of greatest prey density. Consequently, about every four years a major influx of rough-legged hawks should appear in the Tract region. During the winter of 1974-75, this species fed extensively on voles (Table VII-4).

Snowy owls respond in a similar fashion to declines in small mammal populations; but, in contrast to rough-legged hawks, few snowy owls

Table VII-4. USE OF VOLES BY RAPTORS IN THE TRACT C-b STUDY AREA DURING WINTER, SPRING AND SUMMER, 1975.

Species	Total Pellets Analyzed	Total Number of Prey Items	% of Voles In Prey Items
Great horned owl	256	384	80
Rough-legged hawk	49	66	91
Raven	88	60	87

travel as far south as the Piceance Creek Basin, so their occasional dispersal into the Tract region is not expected to influence prey populations to any extent.

It follows that raptors and other predators, capable of widespread dispersal during periods of food shortage, will generally concentrate in areas supporting relatively dense prey populations. Thus, emphasis here will center on the important prey species on the Tract.

Seasonal changes in the Tract's mammalian prey populations, as measured during 1974 and 1975, are described in Chapter V. The highest recorded population density of voles occurred during early fall 1974. Vole populations appeared to decline rather dramatically thereafter and data collected during 1975 suggested this important component of the prey resource did not recover to levels attained by late 1974.

A number of avian predators fed extensively on voles during the period of study, including rough-legged hawks, great horned owls and ravens. Table VII-4 summarizes results of pellet-cast examinations and indicates that voles constituted 91 percent, 80 percent and 87 percent of the diet of the rough-legged hawk, great horned owl and raven, respectively. For the owl and raven these percentages are averages for winter, spring and summer periods. For rough-legged hawks, which are present in the region only during winter, the percentage indicates relative vole consumption during the winter period. Coyotes were occasionally observed "mousing" during daylight periods in agricultural meadows. It is likely these coyotes were feeding on voles, the only diurnally active small mammal regularly inhabiting these meadows. Other mammalian predators probably also hunted voles in these meadows.

All these avian predators, as well as coyotes, have reasonably generalized food habits and are likely to take prey species that are most numerous at any particular time. This is exemplified by seasonal changes in the diet of great horned owls. Over 90 percent of the fall and early winter diet of great horned owls consisted of voles. When this prey supply declined during late winter and spring relative to prey populations of other small mammal species, the voles comprised approximately 50 percent of the diet with deer mice and pocket gophers becoming more important as prey species.

The causative agents stimulating the decline in vole numbers between late fall 1974 and spring 1975 are unknown. Pearson (1966) demonstrated that mammalian carnivores were capable of harvesting as much as 88 percent of the peak standing crop of voles in his California study area and during a Microtus crash, when carnivore populations were high, predators consumed more than 90 percent of the available prey population per month. Because voles generally inhabit relatively open areas and are visible as they move along habitually-used runs, it is probable that rough-legged hawks and other raptors could have similar harvesting capabilities. Raptors combined with mammalian carnivores might have cummulatively impacted Tract vole populations in a major way during winter 1975.

Desert cottontails and white-tailed jackrabbits are potentially important prey species in the Tract area, but the population levels of both are presently low. It appears, however, that both species are becoming more numerous; and, if populations do increase significantly, it is likely that golden eagles and red-tailed hawks, two raptors that prey on cottontails and hares, might also become more numerous. The reproductive success of both of these raptors is often influenced by lagomorph (cottontail and hare) abundance.

During late winter when fewer prey species are available to predators, both avian and mammalian predators tend to concentrate in areas having the largest food supplies. The Tract is of special interest in this regard since winter deer mortalities apparently occur here with greater frequency than in nearby areas of the Piceance Creek Basin. The availability of abundant deer carrion on and close to the Tract might explain why predator scent-station censuses employed in the Piceance Basin have demonstrated higher coyote numbers near Tract C-b than in other censused localities in the basin. The coyote index obtained from the Tract vicinity is approximately twice the average for 20 predator scent-station censuses across the State of Colorado. Many of the larger predators on and near the Tract rely on scavenging dead deer during the winter period. Two instances of deer having been killed by coyotes in the study area have been reported and one observation was made of a pair of golden eagles attacking a fawn. Deer mortality studies have demonstrated that small lateral draws, oriented perpendicular to the main north-south drainages, are areas where large numbers of deer die during winter. Field observations during the winter have relied heavily on sightings of ravens, magpies and golden eagles to reveal the location of dead deer. Observations of the fresh carcasses have demonstrated the importance of this food source to bald eagles, winter visitors to the Tract area. During spring turkey vultures are attracted to these winter-killed deer and it is possible that the relatively high densities of both coyote and turkey vultures in the Tract area can be attributed to the abundance of deer carrion.

3. Aquatic Interrelationships

Variables being measured for aquatic studies consist of "system state variables" and "processes" as detailed in the tables for aquatics. "Driving variables" are measured to some extent in water quality studies. Runoff and stream flow are measured in hydrologic studies. Stream flow is altered by irrigation practices in addition to precipitation. Water temperature, TDS and other parameters are measured as outlined in both aquatic and hydrologic tables.

The aquatic ecosystem in the streams of the Piceance Creek Basin includes interactions between the various organisms studied during the baseline program which aids in recycling materials between the living and nonliving portions of the system. Aquatic communities characteristically undergo seasonal changes in species composition and abundance, as well as changes over a period of years. This is a natural phenomenon. The food web involves the transfer of energy from plants through a series of organisms.

The periphyton of the streams are the major primary producers that convert basic materials into organic substances through photosynthesis. The periphyton are associated with submerged surfaces and include bacteria, algae, protozoans and other microscopic animals and often early stages of organisms that grow to become part of the benthos. Diatoms (Bacillariophyceae) are the most abundant periphyton species in Tract C-b streams. In addition green algae (Chlorophyceae), blue-green algae (Cyanophyta) and euglenids (Euglenophyceae) are also collected. During the first year of study productivity estimates have been made for periphyton utilizing the biomass accumulation technique (APHA, 1971). Estimates of periphyton productivity ranged from 0.002 to 2.029 gm ash-free-dry-wt/m^2/day depending on station location and season. Highest values to date have occurred in September. Lowest values have occurred in winter. Downstream portions of Piceance Creek generally have exhibited the lowest values for periphyton production. The portions of Piceance Creek near the Tract entrance (Stations P-3, P-5 and P-5A) generally have exhibited the highest values for periphyton production. Stewart and Willow Creeks had high values in November.

Aquatic plants (watercress, Potamogeton, Najas,) are an additional source of primary production. The benthos are the plants and animals living on or in the stream bottom. In the stream the majority of these are primarily aquatic insects and larvae. The major groups of insects (Ephemeroptera, Diptera, Trichoptera, Piecoptera and Colcoptera) are represented. Both numerical abundance and biomass estimates have been made for benthos during the first year of study. In Piceance Creek Dipternas and Ephemeropterans are most abundant. Plecopterans, Tri-copterans and Coleopterans were present at most stations but in smaller numbers. The downstream stations in Piceance Creek had a greater abundance of Oligochaetes and other organisms than did the stations in the Tract vicinity. Willow and Stewart Creeks had values similar to Piceance Creek stations with regard to organisms present and seasonal distribution. In the lake stations Dipterans and Ephemeropterans were abundant. Coleopterans were least abundant. Oligochaetes were abundant in summer in Upper Willow Lake. In the White River Ephemeropterans and Tricopterans were most abundant from summer to winter. Plecopterans showed an in-crease during late winter.

Benthic biomass estimates ranged from 0.084 to 20.091 gm/m^2 depending on station and season. Highest values occurred in late summer and early fall at Stations P-2 through P-5A in Piceance Creek. The highest values in Stewart and Willow Creeks occurred in summer. The greatest biomass for all stream stations was found in Stewart Creek at the upstream station. Upper Stewart Lake had the highest values for the lake stations. Benthos and some fish species are the major herbivores in the stream. Benthic invertebrates feed on periphyton, detritus and aquatic vegetation. Some benthic organisms are carnivorous, preying on other benthic species.

The fish populations in the streams surrounding the Tract consist primarily of brook trout, speckled dace and mountain sucker. Population estimates have been made for these species during the first year of study. Mountain suckers and speckled dace are most abundant. Brook trout are the least abundant of the three species.

Mountain suckers and speckled dace are herbivores feeding primarily on periphyton and detritus. Estimates of mountain sucker and speckled dace biomass range from 1.2 to 14.8 gm/m^2. Brook trout are carnivorous feeding primarily on aquatic insects. Estimates of brook trout biomass range from 0.3 to 5.4 gm/m^2.

The diversion of stream water for irrigation purposes has a pronounced effect on stream flow rates during summer months in the vicinity of Tract C-b. Cattle grazing during winter and spring in the meadows surrounding streams affect water quality because of the irrigation return-flow to streams. Turbidity is a problem in Piceance Creek during periods of high runoff (spring) and is reported in Chapter III.

Quantitative measurements have also been made for periphyton productivity, benthic invertebrate biomass and abundance, species diversity and water quality parameters. Material from the various trophic levels is eventually decomposed and converted to nutrients for use by plants and periphyton for photosynthesis. There can be interconnected sequences of conversion as well as simple, isolated interactions.

Selected nutrient levels have been measured at stream and lake stations. Orthophosphate (PO_4) levels have varied from 0 to approximately 0.30 ppm. Nitrate (N) levels have varied from 0.1 to 4.6 ppm. Highest values have occurred in winter. Nitrite (N) levels range from 0 to 0.02 ppm. Ammonia (N) values range from 0 to 0.30. Highest levels have generally been in early spring.

E. Evaluation and Application

Evaluation includes: (1) the collection, summarization and synthesis of baseline information; (2) the identification of knowledge of the system as to the framework of driving variables, state variables and processes; (3) the enumeration of man's potential impacts; and (4) determination of how such impacts will influence system structure and function.

This section includes a preliminary listing of the system variables being measured in baseline studies, an "impact-effect matrix" to be utilized eventually in making predictions of impacts and a preliminary, generalized, diagramatic framework to interrelate structure and function. The discussions herein are preliminary but the structure is sufficiently general to be expanded to include further physical and biological complexity and eventually to introduce sociological, economic, political and other components for a broadened analysis. It should be noted that to complete the conceptual outline presented here is beyond the scope of the Tract C-b baseline studies.

1. Variables and Processes and Their Measurement on Tract C-b

A preliminary listing of the state variables of Tract C-b is given for vegetation (Table VII-5), birds (Table VII-6), "wildlife" (Table VII-7), deer and medium-sized mammals (Table VII-8) and aquatic habitats (Table VII-9). In each table consideration is given to whether or not

Table VII-5 SYSTEM STATE VARIABLES FOR VEGETATION STUDIES*

Now Measured	Potential for Measuring	Degree of Resolution	Not Measured	Potential for Measuring	
Tree Canopy Cover	High	[+]$S_{\bar{y}}$Ca. 10% of y	Tree Biomass	Moderate (expensive)	If effort is great the
Tree Basal Area/Acre			-Root		potential for high
Tree Density			-Shoot		resolution exists.
Shrub Density			Shrub Biomass		However, all except
Shrub Biomass			-Root	Moderate	herb density are diffi-
-Shoot	Moderate	$S_{\bar{y}}$Ca. 25% of y	Herb Biomass		cult parameters to
Herb Cover			-Root	Moderate - High	estimate.
Herb Biomass	Moderate - High	Within 10% of A	Seed Biomass		
-Current Live			Herb Density	Low - Moderate	
-Standing &	Moderate - High	$S_{\bar{y}}$Ca. 20% of y	Cryptogams	High (time consuming)	
Attached Dead			-Density	Low - Moderate	
-Litter & Prostrate			-Cover	(Time consuming -	
Dead			-Biomass	minimal return for	
Soil Chemical &	High			this system)	
Physical Properties					
Air Temperature					
Surface Temperature					
Soil Temperature					
Soil Moisture					
Precipitation					
pH					
Evaporation	Low - Moderate				
Solar Radiation	Low				
Fire					
Runoff	Low - Moderate				
Snow Depth Density	Moderate				
& Distribution					

* Including abiotic parameters

+ $S_{\bar{y}}$ = Standard error of the mean

Table VII-6 SYSTEM STATE VARIABLES FOR BIRD STUDIES

Variable	Measured Presently?	Practicality of Use and Measurement	Resolution (Poor, Moderate, High)
Bird density or density index	yes	Practical -- for monitoring purposes, must be done more intensively in selected locations than present intensity	Moderate (could be higher with additional effort)
Species diversity			
H'	yes	Same limitations as density variable	Moderate (could be higher with additional effort on density)
H' max	yes		
J	yes		
Seasonal species composition	yes	Easily accomplished, but value isn't great unless combined with output from other variables	High
Number of active nests	yes (raptors only)	Easily accomplished	High
	no (songbirds, others	Difficult	Moderate to high (depending on effort in sampling)
Territory size	no	Easily accomplished by multiple flush techniques	High
Mean clutch size	no	Time-consuming to locate sufficient number of nests	High
Mean weight	no	Time-consuming to locate sufficient number of nests	High
Nesting success % fledge vs. no fledge) or total number fledged per nest	no	Impractical without major effort (for passervines; for birds of prey can be easily accomplished)	High
Food availability			
Seed quantity	no	Very practical	High (in local areas)
Insect quantity	(yes)	Plagued with uncertainties	Moderate
Prey mammal quantity	(yes)	Impractical over spatial area necessary	Moderate
Water availability	(no)		
Longevity (average)	no	Highly impractical	Poor - moderate

Table VII-6 Cont.

Variable	Measured Presently?	Practicality of Use and Measurement	Resolution (Poor, Moderate, High)
Pesticide/herbicide concentrations in principal ecosystem components	no		
Physiology (stress measures)			
Adrenal weights, kidney fat, uncertain if this is a reasonable measurement in birds (it is in mammals), subcutaneous fat, etc.	no	Largely untested in wild birds, would require killing large numbers of birds	Moderate
Age class	no	For many species, requires great effort. Important model input	High (for some species)
Nesting phenology	no	Requires much time to locate sufficient number of nests; must separate 1st and 2nd nestings	Moderate - poor
Habitat "structure"	(yes)	Will be highly variable within a population of one species. Physiognomic substances tend to be of overriding importance, and one cannot detect subtle changes in physiognomies with any resolution	Poor
Size of floating population	no	Would require kill removal (extensive) or general removal and retainage in capturing birds	Moderate - high
Parasite - index	no	Would require capturing large numbers for sufficient sample size. Wouldn't "collect" individuals that died of parasitism so would always low estimate	Moderate

Table VII-6 Cont.

Variable	Measured Presently?	Practicality of Use and Measurement	Resolution (Poor, Moderate, High)
Disease - index	no	Same as parasites	Moderate
Competition - index	no	Separation of competition and non-competition agents is largely speculative	Poor

Table VII-7 SYSTEM STATE VARIABLES FOR TERRESTRIAL WILDLIFE STUDIES

Variable	Frequency of Measurement	Units
Small Mammals		
Population Size	Monthly, May-September	#/grid
Density	"	#/hectare
Biomass	Spring and Fall	gm/acre
Reproduction	Monthly, May-September	ave./rep. female/species
Food Habits - Diets	"	% freq. of diet item/species
Activity Index		
Reptiles		
Seasonal Activity Index	Monthly, May-September	
Relative Abundance	"	
Density*	"	
Biomass*	"	
Reproductive Activity	"	
Food Habits*	"	
Sex Ratios*	"	
Population Age Structure**	"	
Arthropods		
Seasonal Activity	Monthly, May-September	
Relative Abundance	"	
Habitat Type, Host Plant, and Order/ Family Comparisons		
Dry Weight		
Abundance		#/acre
Use		deer-days use
Browse Utilization	Spring and Fall	
Cattle		
Abundance	May, June, July, August	#/permit area

*Planned for 1976.
**Possibility to be included in 1976.

Table VII-8 SYSTEM STATE VARIABLES FOR DEER AND MEDIUM-SIZED MAMMAL STUDIES

Methods	Species	Amenable to statistical analysis with present sampling intensity	Level of resolution
Bi-monthly track counts	desert cottontail	occasionally (on snow)	low
	mule deer	occasionally (when densities are high)	low
	coyote	no	
	bobcat	no	
	white-tailed jackrabbit	no	
	badger	no	
	black bear	no	
	elk	no	
	mountain lion	no	
	ringtail	no	
Track counts for evaluating deer migration routes	Mule deer	yes	moderate
Predator scent-post survey	coyotes	yes	moderate
Deer road counts	mule deer	yes	high
Deer age-class determinations	mule deer	yes	moderate
Air reconnaissance	mule deer	no	
	elk	no	
Deer mortality counts	mule deer	yes	high

Table VII-9 SYSTEM STATE VARIABLES FOR AQUATIC STUDIES

Variable	Frequency of Measurement	Units
FISH		
Identification	Bimonthly	Species
Length	Bimonthly	Millimeters
Weight	Bimonthly	Grams
Food Habits	Random	Numbers, volume
Reproduction/Fecundity	Bimonthly	Development stages, No. of eggs produced
Migration	Bimonthly	Distance
Age	Random	Years (Scale Readings)
Population Estimates	Bimonthly	No./100 meter stretch of stream
Length-Frequency	Bimonthly	No./10mm increments
Growth	Random	mm/unit time
Distribution	Bimonthly	No./station
BENTHOS		
Identification	Bimonthly	Genera, Families
Biomass	Bimonthly	Grams/m^2
Densities	Bimonthly	No./m^2
Relative Distribution	Bimonthly	Presence or absence/station
PERIPHYTON		
Identification	Bimonthly	Species
Accumulation (Artificial substrate)	Bimonthly	Dry wt: (gm)/unit area (m^2)
Primary Productivity	Bimonthly	Grams ash-free dry wt./m^2/day
Relative Distribution	Bimonthly	Presence or absence/station

*chlorophyll

Variable	Frequency of Measurement	Units
WATER QUALITY		
Temperature	Bimonthly	^oF
Dissolved Oxygen	Bimonthly	mg/L
Conductivity	Bimonthly	H ohms/cm
pH	Bimonthly	number
TDS	Bimonthly	ppm
Total Alkalinity	Bimonthly	ppm
Total Hardness	Bimonthly	ppm
Cations (5)	Bimonthly	ppm
Anions (10)	Bimonthly	ppm

Table VII-9 Contd.

WATER QUALITY (Contd)		
Nutrients (4)	Bimonthly	ppm
Coliforms (3)	Bimonthly	MPN/100ml.
Streptococci	Bimonthly	MPN/100ml.
Pathogens	Bimonthly	Present/absent
SEDIMENT ANALYSIS		
Moisture	Random	%
T.K.N.	Random	%
C.O.D.	Random	%
Volatile Solids	Random	%
Grain Size Analysis (Tyler Screen)	Random	% Passing/% Retained
Heavy Metals (Spectographic Screen)	Once	%

*Not being analyzed currently

a given variable is being measured, how well it can be measured and related information. These listings of state variables are only a first iteration at developing a uniform and equal understanding of different segments of the system. Future efforts will include expansion and revision of these lists to make them more uniform. Listings of the driving variables being measured need to be made.

Few process studies have been made in the field. In a large part this is because of the complexities involved in making these measurements. Many data are available, however, from laboratory studies on species in and related to those in the C-b Tract region and such information can be extracted from the literature. A brief consideration of some key processes in the C-b Tract is given in Table VII-10.

2. Man's Potential Impacts

A major purpose of the biological baseline studies is to provide a description of conditions existing on Tract C-b prior to the initiation of development activities. When development activities begin, biological monitoring studies will be underway which will provide a means to compare the biological components of the Tract at that time with those present during the baseline period. Any impacts generated by development activities will be assessed. Impacts are addressed here to: 1) provide a focus on those elements of the system where impacts caused by development might be anticipated and 2) initiate considerations of control strategy alternatives to quantify and mitigate these impacts. Figure VII-17 is a preliminary matrix of some of these areas of potential impact.

Impacts may affect the structure or functioning of the ecological system. Impacts on structure may be direct in nature, for example, the clearing of trees adjacent to a road, or indirect as in the case of a decrease in predators in the Tract area owing to a decrease in prey populations because of habitat alterations. Structural units of importance to elements of the biological system, such as ridges used for migration of the mule deer herd, may be disrupted as a result of barriers being erected in the form of oil-shale-plant or mine facilities. Distribution of certain animal species may be altered in response to increased human activity, traffic and noise associated with oil shale development.

Impacts on the function of the biological system may also be either direct or indirect in nature. An example of a direct impact would be an increase in emigration of a species owing to increased activity. This would result in the structural distribution change mentioned above. An indirect impact on function could result from habitat alterations leading to a decrease in food availability which in turn might lead to a decreased reproductive rate.

Possible impacts on the water system related to oil shale development could affect both water quantity or distribution and water quality. The major potential for changes in water quantity and distribution arises from dewatering of the mine. Mine dewatering might lower the water table in the deep aquifers over a wide area surrounding the mine.

Table VII-10 EXAMPLES OF PROCESSES OPERATIVE AT C-b TRACT

Process Rates	Measured Presently?	Practicality of Use and Measurement	Resolution Poor, Moderate, High
Natality Rate	No	Very difficult in free-living Populations	Poor - Moderate
Mortality Rate	No	Very difficult in free-living Populations	Poor - Moderate
Recruitment Rate	No	Requires natality, mortality, immigration and emigration data. Can't be inferred from number of territ. males becoming floating population. Density estimates generally don't acct. for most of floating population, so recruitment can't be inferred from density	Poor - Moderate
	No	Waterfowl as bird-use days during migration	Moderate - high (waterfowl) Poor - moderate (others)
Predation Rate	No	Exceedingly difficult	Poor - Moderate
Growth Rate	No	Time consuming, but can be accomplished readily	High
Metabolism Rate	No	Can be calculated from wts. and ambient temp.	Moderate
Migration Flux	No	Can be determined for migrating	

Now Measured:	Potential For Measuring:	Not Measured:
Decomposition: Surface 10 cm depth	Moderate - High	Estimates General
Net Primary Productivity: Shoot only - Herbs Shrubs	Moderate	Std. error of the mean ca. 25-30%
Tree Growth	Moderate - High	

Potential for Measuring:	Degree of Resol.:
Autotroph Respiration	Low
Plant Tissue Mortality	Moderate
Seed Productivity	Moderate
Nutrient Cycling	High but Expensive
Photosnythesis	Moderate (expensive)

Depending upon unknown hydraulic connections between these deep aquifers and surface springs and seeps, ground water flow to Piceance Creek and its tributaries might be substantially reduced. If the mine inflow water is consumed by the retorting plant, a net loss from the hydrologic system will result. If the mine inflow water is reinjected underground, there will be no overall net loss from the system but a redistribution may occur which might reduce surface flows in some or all areas and possibly increase surface flows in some areas. If the mine inflow water is released to surface streams, a temporary increase in stream flows would result which might be balanced by a decrease of equal magnitude after the cessation of mine dewatering efforts.*

Importation of surface water from other areas, such as the Colorado or White Rivers, could result in a local increase in the ground water table because of seepage from the reservoir. Construction of plant buildings, roads and other hard-surfaced areas will alter the hydrologic balance by increasing runoff from these areas during rains. It is planned to contain most of this runoff behind the Sorghum Gulch dam. Since the major portion of precipitation in the Tract area is normally returned to the atmosphere through evapotranspiration, some small effects on local climate may result.

Impacts on water quality could occur in various ways if mitigating efforts are not pursued. Discharge of mine inflow water to surface streams would increase the concentrations of many harmful trace materials, particularly fluoride. Temporary disposal of this water by sprinkler irrigation in Sorghum Gulch would increase fluoride levels in soil and vegetation. If reinjected, the quality of water in the aquifer, and therefore possibly in springs connected to the aquifer, could be lowered by inclusion of lower-quality inflow water from below the mining zone and by contact of the inflow water with crushed rock within the mine.

Increased concentrations of both suspended and dissolved solids in runoff water will occur in areas subject to earth moving and construction activities. Runoff, if any, from the spent-shale disposal pile will contain high levels of salts and trace organic constituents. If moisture should be allowed to seep through the pile, contamination of the alluvial aquifer might result. Air-borne emissions from the processing plant and fugitive dust from the ore-handling areas may be entrained in rain and snow and added to stream loads. While most of the possible effects mentioned are quite small, they have a cumulative effect on water quality. Prevention or mitigation of such effects must be a major concern at all times.

Air quality will be affected by the addition of dust, hydrocarbons, carbon monoxide, sulfur dioxide and nitrogen oxides as a result of construction activities, day-to-day plant operations and the increased population anticipated. The plant will also generate quantities of stream and water vapor and some odors characteristic of oil shale retorting operations.

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*This paragraph is supposition. At the present state of the baseline program, data indicate minor dewatering problems which effects can be mitigated by proper planning; and, further, data do not indicate any connection between the deep aquifers and the springs. See III F.2. Water Relationships & III F. 3. Dewatering Effects p. 99 ff.

The area primarily affected by these pollutants will be the Tract and the immediate area surrounding the Tract as a result of various construction and operational activities. Piceance Creek valley and the surrounding area may also be affected as a result of plant emissions, road construction and improvement and daily traffic to and from the Tract during construction and operation. To a lesser extent the multi-purpose corridor to the south of the Tract will be affected by the construction of shale-oil, ammonia, LPG and water pipelines. Construction of communication systems and power lines will have a small effect on air quality. Staging areas, terminal facilities and railroad sidings located near Rifle will also be slightly affected by activities. Diffusion models will be used for the prediction of ambient air contaminant concentrations resulting from operation of the plant and emissions from auto and truck traffic. Such models will be used to demonstrate compliance with existing federal and state ambient air-quality standards.

Some small, local effects on the climate could occur during the plant operation; these effects can be described as follows:

- Increased air temperatures in the immediate vicinity of the plant complex will be produced by the active portions of the processed-shale embankment and by hot stack gases. The impacts of the resulting convection currents upon local wind patterns and air turbulence above the plant should be insignificant. The topographical changes produced by the process-shale embankment may affect local meteorological patterns to a small degree.

- Releases of water vapor could sightly increase local humidity and downwind precipitation. Evaporation and the various water vapor releases do constitute a return of water to the ecosystem and can therefore be considered a positive impact. Under certain conditions, water vapor carried by cold air draining into the valleys could increase the formation of fog. The release of water vapor and other emissions may slightly reduce solar radiation as measured on the surface.

- The heat release from plant stacks and the processed-shale pile in Sorghum Gulch may slightly effect diurnal wind patterns. This heat could interfere with typical early evening drainage of air into Piceance Creek Valley in the vicinity of Sorghum Gulch. The cumulative effect is expected to be insignificant, but positive.

- The rate and intermediate steps involved in the ambient chemcial reactions,which generate the combination of products commonly identified as "smog,"are influenced by many complex factors. These include the relative concentrations of reactants, the degree of photoactivation, variable meteorological dispersive forces and the influence of local topography, temperature and relative amounts of moisture. Meteorological dispersion is, in turn, related to the degree of containment beneath inversions, the magnitude of horizontal and vertical wind movements, the degree of turbulence induced by convective and non-linear flow and precipitation. The systems which produce smog are so complex and

and variable that reliable predictions of this type of air pollution are unattainable at the present time. More sophisticated technology will have to be developed before adequate prediction of this phenomenon can be made.

The operational air quality control plan will consider fuels management, practical use of tall stacks, pollution control equipment and careful monitoring for potential air-pollution episodes. Continuous ambient air quality monitoring is being conducted during the baseline phase and will be continued during the development and operation phase for various gases and particulates to detect any air quality changes that may occur. During the plant operation monitoring of stack emissions will be accomplished in compliance with appropriate regulations and guidelines.

Changes in the above driving variables, such as local and regional climatic features, as well as changes in important system state variables, such as soil moisture, will be reflected in the structure and function of plant communities and in the animal populations which they support. These changes are not clearly identifiable at this time; neither are they presently quantifiable. The introduction of chemical pollutants into air, soil or water will also influence vegetation and wildlife. The kind and magnitude of these influences cannot be directly stated at this time.

The purpose of this subsection has been to identify potential categories of impacts (Figure VII-17). During the course of developmental procedures actual impacts will be clearly defined and quantified and will be applied to this matrix-type of approach.

3. Conceptual Approach to Structure-Function Relationships

This section provides an initial approach to the framework of interrelating ecosystem structure and function and shows how ecosystems interact with the human factors potentially operative on the Tract.

Figure VII-18 illustrates coupling among organisms and water within and between three plant communities. The concept can be extended readily to other important communities as noted in Chapter V of this report. Figure VII-18 includes the following general features:

- Major columnar areas represent different plant communities as noted in Chapter V.

- The trophic levels are also identified as to whether the organism is or is not restricted to that particular plant community type.

- In the case of herbivores it is also necessary to distinguish between those who are restricted to a single species or group of vegetation and those that are non-restricted in the dietary selectivity.

VARIABLES, PROCESSES INFLUENCED	Increase in people	Increase in traffic	Clearing of Vegetation	Barriers to Movement	Erosion	Hunting	Grazing	Noise	Paving	Companion animals	Airflow pattern changes	Fugitive dust	Drainage water	Toxic water storage	Steam emissions	Acid rain	Groundwater changes	Gaseous effluents	Particulates effluents	Microclimate changes	Solid waste	Plantings	Fire	Stocking	Laws & Standards	Irrigation	BOD	Spent Shale Piles	Other Recreation
	IMPACT VARIABLES OR CONTROLS																												
Plant biomass																													
Animal biomass																													
Plant distribution																													
Animal distribution																													
Species diversity																													
Animal numbers																													
Emigration																													
Immigration																													
Mortality																													
Reproductive rate																													
Regeneration Productivity																													
Migrational behavior																													
Daily movements																													
Soil moisture																													
Soil pH																													
Soil temperature																													
Snow cover																													
Runoff Water quality																													
Stream flow																													
Water temperature																													
Air temperature																													
Evapo transpiration																													
Interception																													
Sedimentation																													
Infiltration																													
Diffusion																													
Predation																													
Competition																													
Food Availability																													
Social Behavior																													
Microbial Activity																													
Microorganism Biomass																													
Spore Germination																													
Recreation																													

Figure VII-17 AN INITIAL "IMPACT-EFFECT MATRIX" FOR TRACT C-b IN RELATION TO OIL SHALE DEVELOPMENT

- The assumption is made that the decomposer organisms are general in their activity in that they act upon and degrade all classes of vegetation and animal material.

- Soil water is identified at different layers in the soil. The number of layers may be different in the various plant communities.

Figure VII-18 shows a way that energy and matter may flow from one plant community to another. The major flows between communities occur via animals or via water flow. The non-specific, non-restricted carnivores and the non-specific, non-restricted herbivores may move through the different communities and landscape units throughout the year. In any given period of the year, however, they may be restricted to one or more of the plant-community zones.

There is coupling both within the different trophic-level groupings within a subsystem unit as well as in many instances between subsystem units.

Figure VII-18 provides an orderly way of illustrating the great degree of complexity existing in the C-b Tract ecosystems. The diagramatic approach used in Figure VII-18 combines features from both the relational diagrams and the flow diagrams used in above sections. This diagramatic approach can be adapted easily to the large number of community units and trophic groups occurring in the system. It identifies each of the major flows of concern as well as each of the major compartments within the system.

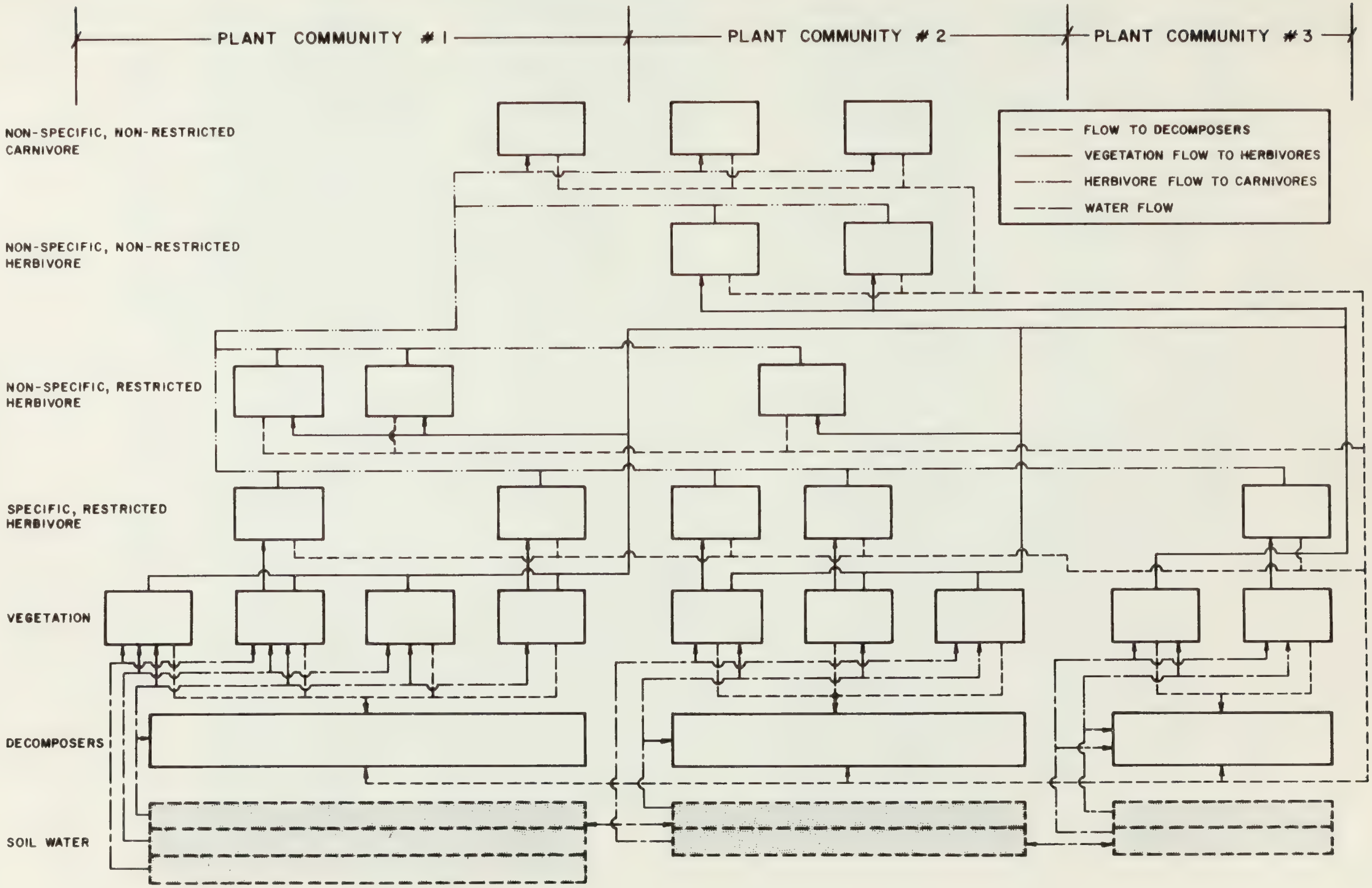
A potential major step would be to expand the type of diagram given in Figure VII-18 in several ways: (1) include all key organisms of each major community; (2) incorporate into the flow diagram some of the human components; and (3) list the major factors affecting each flow. To accomplish (2) above, Figure VII-18 would simply become a subsegment of a larger diagram. The larger diagram would include perhaps the following subsystems:

Subsystem	Material Flowing
Biological	Biomass
Hydrologic	Water
Land Use	Area
Human Population	People

Each of these subsystems would have its own series of variables and processes. For example, land use variables might include the following land categories: urban, agricultural, recreational and industrial. The population variables might include employment categories of agriculture, industry, business and government.

Another task could be done to illustrate for each process or flow occurring in the diagrams the factors influencing it. This would result in a large table of the following form:

Figure VII-18 VARIABLES AND RATE PROCESSES IN DIFFERENT SPATIAL UNITS OF TRACT C-b



FACTORS INFLUENCING

Process	Driving Variables				State Variables				
	1	2	3	... n	1	2	2	...	m
1	X	X	0	...	0	X	X		
2	X	0	X	...	X	X	0	...	
3		.				.			
.		.				.			
.		.				.			
p									

The evaluation process is concerned with quantification of variables and processes affected by the project. Estimates are sought for those quantities which suffer major perturbations, followed by possible studies of management control strategies to mitigate the impact. The technique serves to rank items of major import, to identify possible variables which should be measured and to identify those variables which can be dropped from further consideration and measurement. Often this technique is referred to as sensitivity analysis.

F. Summary

A systems approach has been used in an initial effort toward conceptualizing the overall system. The overall system includes ecological, economic, sociological and political components. The main focus has been on conceptualizing the driving variables, system state variables and processes of the biotic and abiotic parts of the ecological systems in the C-b Tract. This section illustrates an initial diagramatic framework, how the biological system can be structured, how it functions and how it can be coupled to the land use, population, industrial and other subsystems of the oil shale development region. Processes, which account for the transfer of matter and energy in the system, have been structured in a hierarchical format. Each process needs to be related to the factors influencing it, many of which are man-controlled.

The framework described above is sufficient to perform qualitative analyses of the impacts on ecological components because of man's manipulations of the overall system. For quantitative analyses it will be necessary to describe functional relationships among the variables. In either case our evolving framework provides a structure in which to embed and interrelate information obtained in the baseline studies and in subsequent monitoring measurements.

VIII SCENIC AND ARCHAEOLOGICAL VALUES

A. Scenic Values

1. General Introduction

A study was undertaken to determine the type and quality of the scenic resources existing in the Tract area. The scenic elements of the Piceance Creek Basin were related specifically to the Tract and generally to the scenic resources of surrounding areas. This information was then used to define and evaluate areas of visual sensitivity on the Tract.

The methodology and guidelines used in this study were taken from the U. S. Forest Service's Visual Management System (USDA Handbook No. 462). A diagrammatic representation of this methodology is shown in Figure VIII-1 which illustrates the sequence of steps leading to the determination of visual sensitivity levels of the landscape. The study area covered the Tract and a zone within 4 miles of the Tract boundary. A discussion of each phase of the study follows.

2. Landscape Factors

a. Character Type

Visual-character type is based on common distinguishing visual characteristics of an area. Character type is determined by the physiographic sections as defined by Fenneman (1931).

The Piceance Creek Basin is included in Fenneman's Uinta Basin physiographic section. The Uinta Basin section is bounded on the north by the Uinta Mountains, on the east by the Park Range and on the south by the Book Cliffs. In general the interior of the Uinta Basin section, which is topographically higher than the margins, is characterized by a series of high plateaus separated by the major drainages of the region.

b. Character Subtypes

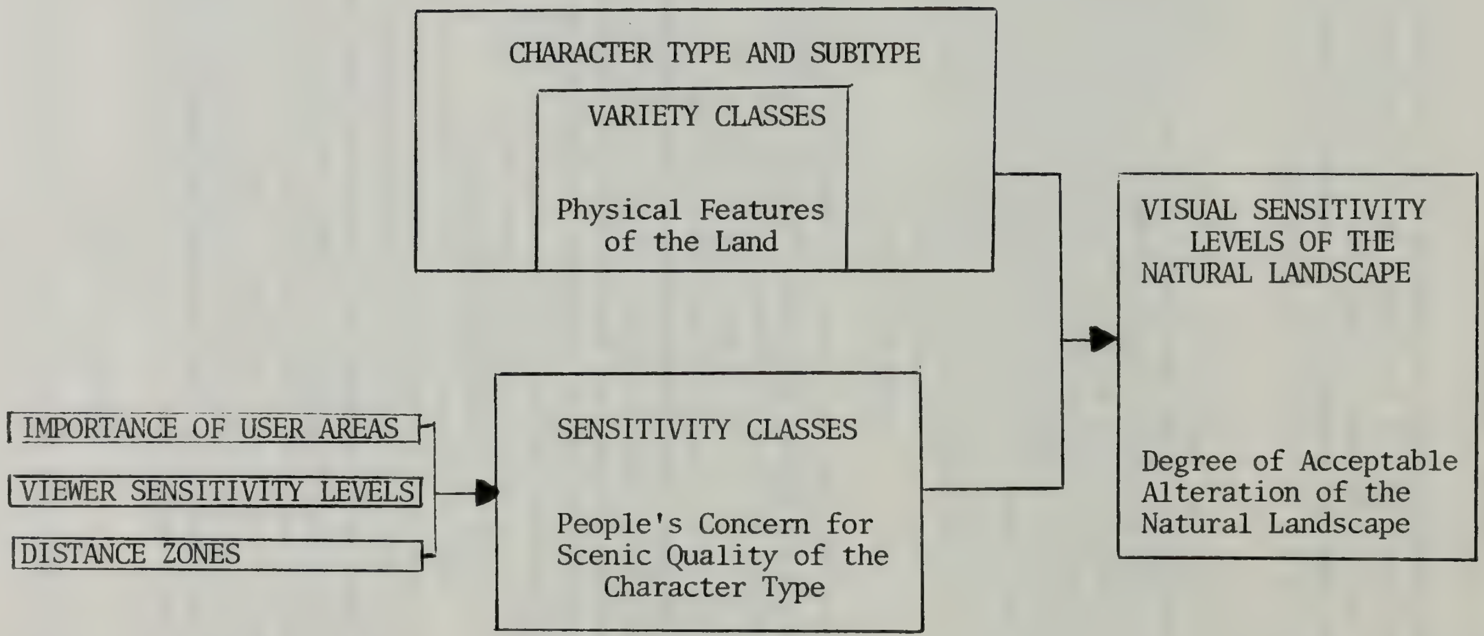
To more effectively describe the landscape types of the region, visually-distinct subtypes of the character type can be defined. Visual subtypes described in this study are: Piceance Creek Basin, Book Cliffs, Roan Cliffs, Colorado River Valley, Grand Mesa, Grand Hogback, Colorow Mountains, Flattops and Cathedral Bluffs-Douglas Creek.

When compared with most of the other subtypes, it is evident that the Piceance Creek Basin is less notable in terms of strength of form and line, but ranks equally with regard to color and texture variations.

c. Variety Classes

Within the confines of the Piceance Creek Basin there are consid-

Figure VIII-1 USFS VISUAL MANAGEMENT SYSTEM



erable variations in landform, rockform, vegetation and waterforms. These variations are defined by a series of variety classes which account for the inherent scenic quality of the landscape.

A series of criteria set forth in Table VIII-1 were used to differentiate the variety classes (distinctive, common or minimal) which exist in the Piceance Creek Basin. It was convenient to identify the distinctive and minimal areas on a map and to assume the remainder are common. A map of variety classes is shown in Figure VIII-2. The cliffs at the mouth of Scandard Gulch are the only distinctive area found on the Tract. Several other distinctive areas are located off-Tract; most of these also consist of dominant rockforms. The minimal variety classes in the study area are quite extensive and cover a considerable portion of the Tract and nearby areas to the west. These areas have been chained within the past 10 years.

3. Human Factors

To account for the human aspects of the visual experience in this scenic quality analysis the methodology includes a measurement of the relative importance of use areas, water bodies and travel routes, viewers' concern for scenic values and the distance from which the landscape is viewed.

a. Importance of User Areas

User areas such as roads, trails, overlooks, camp sites, ranch headquarters, cow camps, ponds and streams are rated as being of primary or secondary importance based on size, volume of use, duration of use, recreational use and local importance. In this study, user importance was considered only in terms of use factors within the Piceance Creek Basin (Table VIII-2). User volume, duration of use, and size were the criteria used to differentiate the primary and secondary user areas shown in Figure VIII-3.

The only travel routes of primary importance are the Piceance Creek road and the Collins Gulch road. Piceance Creek road is used by local residents, drilling crews and government agency personnel. It is not a scenic highway; in fact, until it was completely paved several years ago, it did not appear on many highway maps. Collins Gulch road serves the employees of a gas absorption plant located north of Tract C-b. All other roads were classed as secondary importance because the lesser traffic volumes and seasonal use. These roads are used primarily by local ranchers for movement of cattle and sheep and by hunters seeking deer and elk. User areas of primary importance are the ranch headquarters, all of which are situated on the Piceance Creek road. All other use areas and water bodies were classed as secondary in importance because of the low volume of general use and low recreational use.

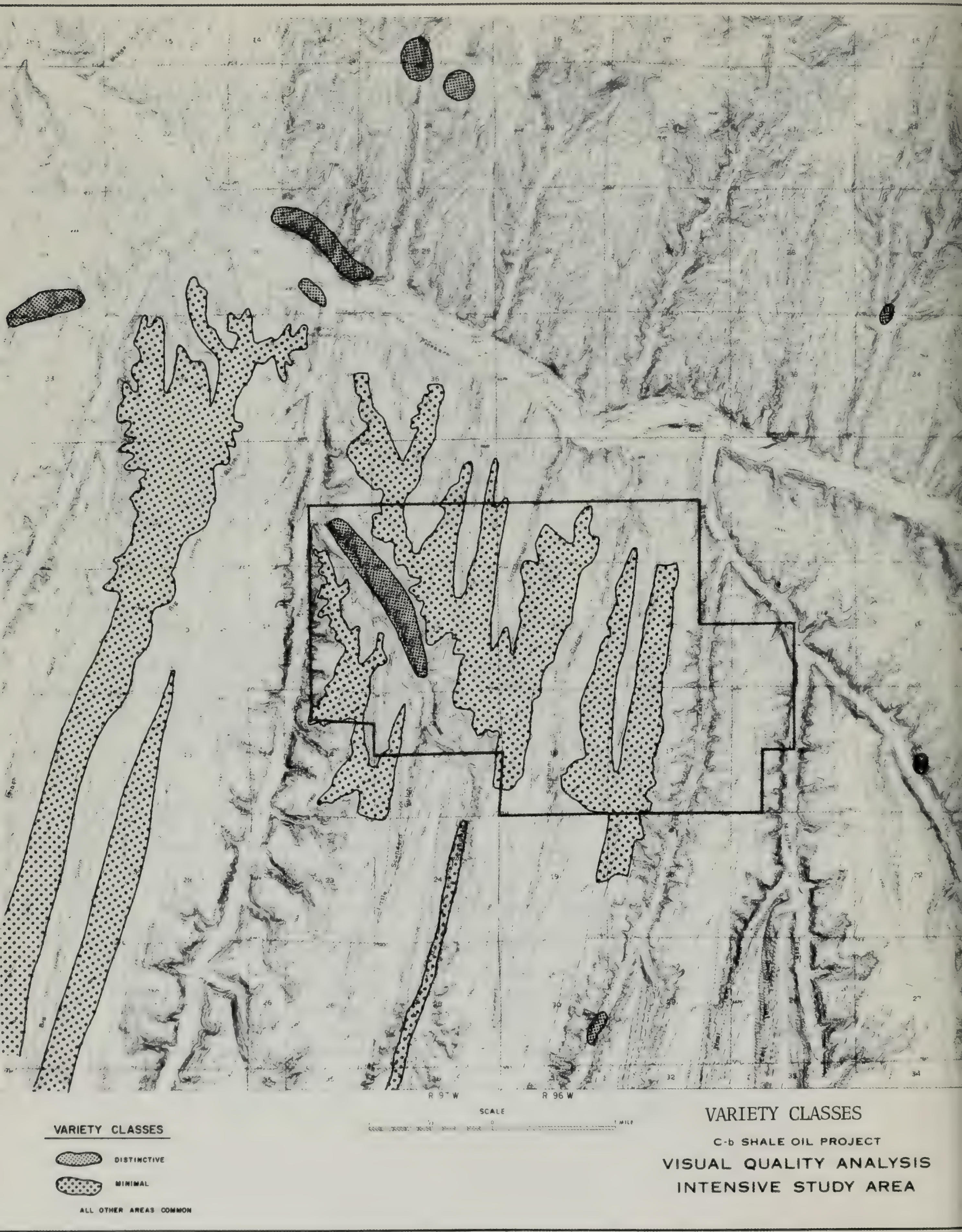


Figure VIII-2

Table VIII-1

VARIETY CLASSES DETERMINATION*

	DISTINCTIVE	COMMON	MINIMAL
LANDFORM	Cliffs on valley sides Highly eroded slopes	Moderately steep valley sides, flat ridge tops, and flat valley bottoms	Extensive flat ridge tops or valley floors
ROCKFORM	Rock features which stand out on landform Unusual rock strata exposures	Rock features obvious but do not stand out	Rock features small to nonexistent
VEGETATION	High degree of patterns in vegetation High diversity in plant forms Relatively large stands of trees	Continuous vegetative cover with some degree of pattern Low diversity in plant forms Irrigated meadows	Continuous vegetative cover with little or no pattern Chained or sprayed areas Non-irrigated valley bottoms
LAKES, PONDS	Irregular shorelines Greater than one acre in size	Regular shorelines Less than one acre in size	No lakes or ponds
STREAMS, SPRINGS AND SEEPS	Springs and seeps which form ponds Perennial streams Large volume	Springs and seeps which do not form ponds Ephemeral streams Low volume	No streams, springs or seeps

*Only one of the criteria had to be met for an area to be classed as Distinctive, whereas two or three criteria had to be met for an area to be classed as Minimal. This allowed Distinctive areas to be readily identified while Minimal areas needed considerably more factors for them to be classified.

Table VIII-2
USER AREA CRITERIA

	PRIMARY IMPORTANCE	SECONDARY IMPORTANCE
TRAVEL ROUTES Roads Trails	High use volume Major access road Long use duration	Low use volume Project road Short use duration
USE AREAS Overlooks Camp areas Ranch headquarters Cow camps	Large size Long use duration High use volume	Small size Short use duration Low use volume
WATER BODIES Ponds Streams	High recreation use	Low recreation use

Figure VIII-3

b. Viewer Sensitivity Levels

To account for the concern for scenic values which the users of the Piceance Creek Basin have, a matrix was developed showing the importance of user areas and an appraisal of the percentage of users having some concern for scenic values. The matrix is shown in Table VIII-3.

The concern for scenic values is based on the percentage of viewers. The U. S. Forest Service method assumes that persons having a major concern for scenic values are those engaged in driving for pleasure, hiking scenic trails, camping at primary use areas, or using lakes and streams for other recreational activities. Minor concern for scenic values is assumed to be held by persons involved in daily commuter driving or hauling forest products or employed in other commercial uses of the forest. On this basis less than 10 percent of all Piceance Creek Basin users are estimated to have a major concern for scenic values. Given this estimate there are no primary sensitivity levels. However, since no hard data were available on which to base this 10-percent estimate, a liberal approach was taken by assuming that users had some concern for scenic values. This permitted all sensitivity levels to be represented.

The Piceance Creek road and the ranch headquarters were placed in sensitivity level 1. It was assumed that at least 25 percent of these users had some concern for scenic values. Collins Gulch road was judged to have fewer users concerned about scenic values and thus was placed in sensitivity level 2. All other roads in the study area were also placed in sensitivity level 2. While they are of secondary importance, a considerable number of users (deer hunters and local ranchers) were assumed to have some concern for scenic values while engaged in their primary goals. All areas not seen from any travel route or use area were placed in sensitivity level 3, the lowest level.

c. Distance Zones

One method of determining how different sections of the study area are viewed by users is to define distance zones, view the landscape from each user area and prepare a distance-zone map for each user area. The criteria used in defining each distance zone are shown on Table VIII-4. In conjunction with the distance-zone mapping, sensitivity levels were determined for each area. All distance-zone maps were overlayed and sensitivity levels were used to set priorities in developing the composite distance-zone/sensitivity-level map shown in Figure VIII-4. In all cases the most restrictive sensitivity level was used in the composite map.

d. Sensitivity Classes

The final step in depicting sensitivity classes is to overlay the variety class map with the distance-zone/sensitivity-level map. The U. S. Forest Service method is designed to produce a final map showing quality objectives and recommending management methods to accomplish

Table VIII-3

VIEWER SENSITIVITY LEVELS

User Area	Viewer Sensitivity Levels		
	1	2	3
Primary	At least 1/4 of users have SOME concern for scenic values (PICEANCE CREEK ROAD AND RANCH HEADQUARTERS).	Less than 1/4 of users have SOME concern for scenic values (COLLINS GULCH ROAD)	
Secondary	More than 3/4 of users have SOME concern for scenic values.	Between 3/4 and 1/4 of users have SOME concern for scenic values (ALL OTHER INTENSIVE STUDY AREA ROADS)	Less than 1/4 of users have SOME concern for scenic values (AREAS NOT SEEN FROM ANY USER AREA)

Table VIII-4

DISTANCE-ZONE CRITERIA

	Foreground	Midground	Background
Distance (miles)	0 to 1/4-1/2	1/4-1/2 to 3-5	3-5 miles to infinity
Sight capacity	Detail ⟷		No detail
Object viewed (example)	Rock point	Entire ridge	System of ridges
Visual characteristics	Individual plants & species	Texture and Form (conifers/ hardwoods)	Patterns (light and dark)

Table VIII-5

SENSITIVE AREAS - QUALITY OBJECTIVES COMPARISON

Sensitivity Class	USFS Visual Quality Objective	Degree of Acceptable Change
A	Retention	Should not be evident
B	Partial Retention	Should be visually subordinate
C	Modification	May be visually dominant but must possess visual characteristics of natural landscape.
D	Maximum Modification	May be visually dominant but must possess visual characteristics of natural landscape when viewed as background.

these objectives. In this study the quality objectives have been changed to sensitivity classes as shown in Table VIII-5. A matrix developed by the U. S. Forest Service (Table VIII-6) was used to arrive at the sensitivity-class map (Figure VIII-5) to depict the baseline scenic quality of the study area.

4. Visual-Management Guidelines

The U. S. Forest Service has developed management guidelines for retaining the scenic quality of lands under its control. The C-b Shale Oil Project will use these same visual-management guidelines in all planning, construction, reclamation and mining operations. Planned activity on the Tract will not affect areas of high visual sensitivity. In the event that development activities must take place in areas of high visual sensitivity, these activities will be designed to minimize the visual impact of the activity. The level of visual sensitivity of each area proposed for development will consider one of several criteria (ecological, economic, hydrological, meteorological) used in Tract planning and construction. The level of visual sensitivity of the affected area will be a factor in determining design modifications necessary to minimize visual impact.

The visual management guidelines for each sensitivity class are:

Class A - Development activities may only repeat form, line, color and texture which are frequently found in the landscape. Changes in their size, amount, intensity, direction and patterns should not be evident. Reduction in form, line, color and texture contrast owing to development should be accomplished either during construction or immediately thereafter by such means as seeding vegetation clearings and cut-and-fill slopes, hand planting large plant stock or painting structures.

Class B - Development activities may repeat form, line, color or texture common to the landscape. Changes in size, amount, intensity, direction and pattern should remain visually subordinate to the landscape. Activities also introduce form, line, color or texture which are found infrequently or not at all in the landscape, but they should remain subordinate to the visual strength of the landscape. Reduction in form, line, color and texture contrast owing to development should be accomplished as soon after construction as possible, but no more than one year later.

Class C - Development activities may visually dominate the original landscape; however, activities of vegetative and land-form alteration must borrow from naturally established form, line, color and texture so completely and at such a scale that visual characteristics are those of the natural landscape. Additional parts of these activities such as structures and roads must remain visually subordinate to the proposed composition. Activities which involve the introduction of facilities such as buildings, signs and roads should borrow from the existing

Figure VIII-4

Table VIII-6

SENSITIVITY CLASS MATRIX *

Variety Class	Distance-Zone/Viewer-Sensitivity Level						
	Foreground, level 1	Midground, level 1	Background, level 1	Foreground, level 2	Midground, level 2	Background, level 2	Not Seen level 3
Distinctive	A	A	A	B	B	B	B
Common	A	B	B	B	C	C	D
Minimal	B	B	C	C	C	D	D

*Sensitivity Classes

A
B
C
D

Decreasing Sensitivity

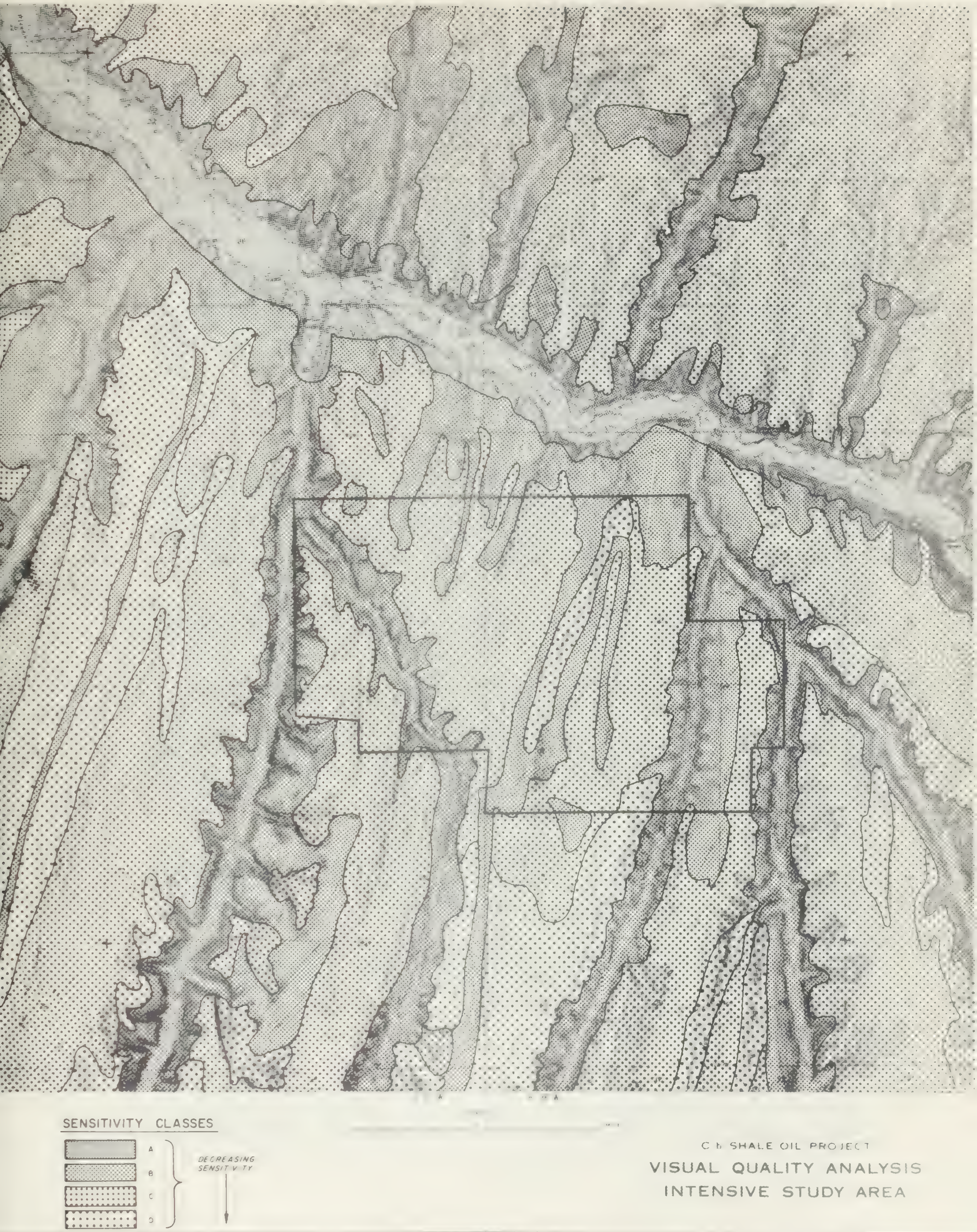


Figure VIII-5

forms, line, color and texture so completely and at such a scale that the visual character is compatible with the natural landscape. Reduction in form, line, color and texture contrast due to development should be accomplished in the first year or at a minimum should meet existing regional guidelines.

Class D - Development activities may dominate the landscape; however, when viewed as background, the visual characteristics must be those of the natural landscape. When viewed as foreground or middle ground, they need not borrow from the natural form, line, color and texture. Alterations may also be out of scale or contain incongruent detail when viewed as foreground or middle ground. Introduction of additional parts of these activities such as structures and roads should remain visually subordinate when viewed as background. Reduction of contrast in form, line, color and texture owing to development should be accomplished within five years.

5. Conclusions

The Piceance Creek Basin was found to have low scenic value when compared to the other landscape types of the region. It contains marginal strength of form and line when compared to such areas as the Book Cliffs, Roan Cliffs, Grand Mesa and the Flattops. It rates about equally with these with regard to color and texture. On a regional basis the Piceance Creek Basin has an extremely low visual character.

The scenic values of the Piceance Creek Basin were evaluated solely within the context of the basin itself. A four level rating scale was developed based on the U. S. Forest Service Visual Management System. Within the Piceance Creek Basin proper, the only Class A area near Tract C-b is the Piceance Creek road corridor. The Tract is located in an area determined to be of sensitivity Classes B and C. The sensitivity Class B areas include the principal drainage cutting through the Tract. The Class C areas comprise the chained regions, which cover some 50 percent of the Tract. The bottom of the on-Tract portion of Sorghum Gulch was rated as Class D since it is not visible from any user area.

The assumptions made in this study were designed to maximize the scenic values which do exist in the Piceance Creek Basin. As stated earlier, these values are marginal when compared to those existing in contiguous areas of Western Colorado. The final map is a liberal interpretation of the Piceance Creek Basin's scenic values, since most users' cone-of-vision does not expose them to many of the side gulches which contain the basin's distinctive landscapes. This was most evident to the field investigators who had considerable familiarity with the area but still found access to much of it solely as a result of doing this study.

It should be emphasized that this methodology accounts for scenic qualities seen by the majority of basin users. It does not account for small isolated areas that an individual hiker or hunter might encounter

when traveling off established travel routes. Such areas are subject to extremely individual preferences that no methodology designed to study regional scenic values can accommodate.

B. Archaeological Values

1. Introduction

A detailed baseline study of the cultural resources of Tract C-b has been conducted to identify sites of past human activity in the Tract area, relate these sites to contemporaneous activities in the region, and assess the scientific value and historical significance of each site.

Previous archaeological work in the Piceance Creek Basin, including a reconnaissance of the Tract, was carried out by Colorado State University in cooperation with Thorne Ecological Institute of Boulder, Colorado, during the summer of 1973. That work was done as part of the Regional Oil Shale Study for the Colorado Department of Natural Resources (ROSS #5). Other field work in the Piceance Creek Basin has been carried out by the University of Denver and Southern Colorado State College in connection with other oil-shale projects.

A majority of the detailed field work on Tract C-b was conducted in August 1974. A total of 2640 acres was intensively examined. Examination of drill sites and other potential disturbed areas that were not included in the initial studies has been conducted since then.

A quadrat system of quarters of public-land-survey sections was used for the detailed field survey of the Tract. The quadrats were laid out in a checkerboard pattern and each sample quadrat was examined by three or four investigators. All sites encountered were recorded on Archaeological Survey site inventory forms included in the Quarterly Data Reports. None of the sites had enough artifacts to warrant any attempt at systematization or standardization. All the artifacts were catalogued in the Colorado State University system and are stored at Colorado State University. Figure VIII-6 shows the areas surveyed and identifies the sites.

2. Cultural Resources - Prehistoric Sites

Four prehistoric archaeological sites have been recorded on the Tract and in immediately adjacent areas, as shown on Figure VIII-6.

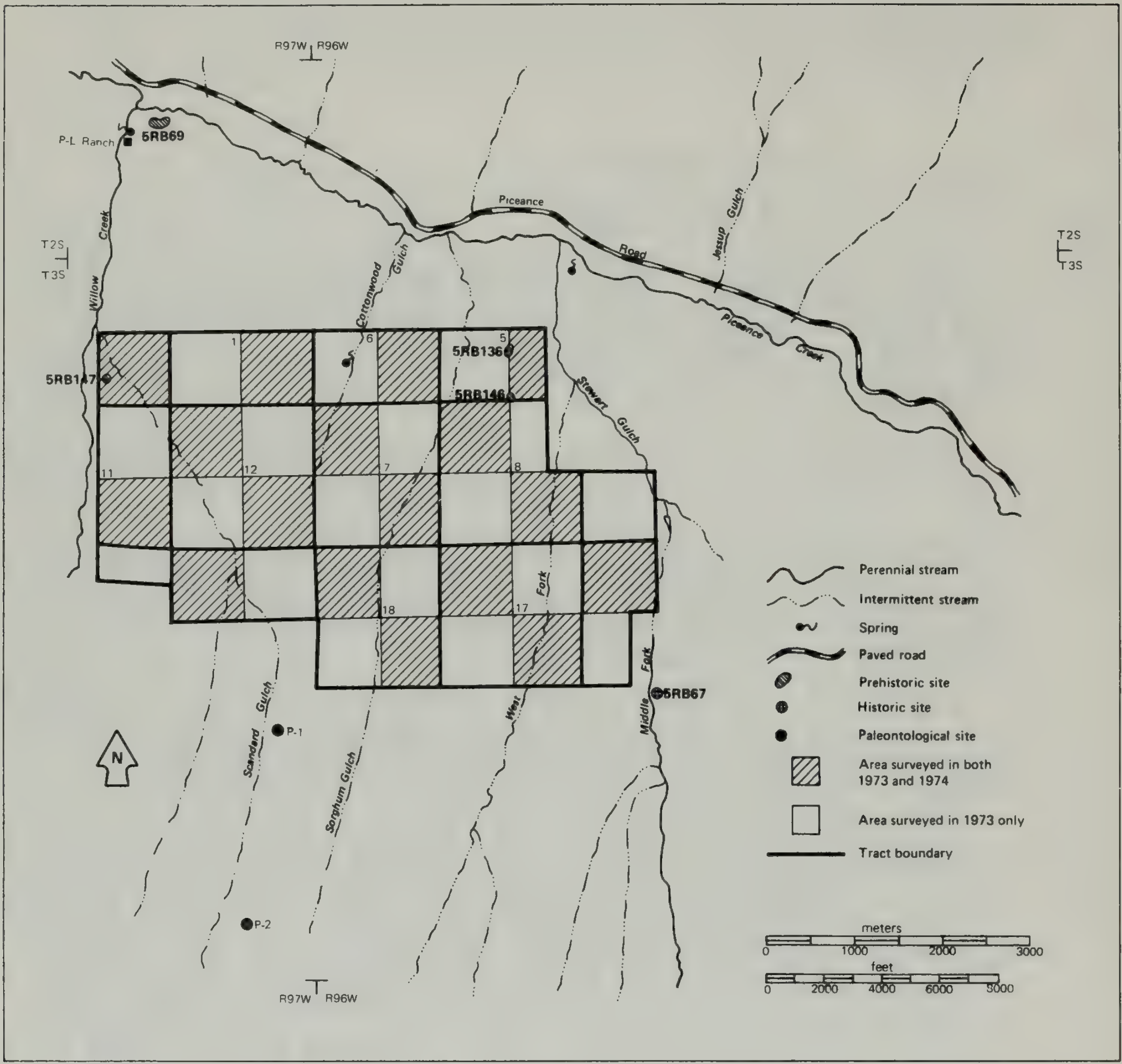


Figure VIII-6 ARCHAEOLOGICAL AND PALEONTOLOGICAL SITES, TRACT C-b AND VICINITY

The Tract has been intensively examined for antiquities, but in the adjacent areas site discovery has been the result of chance encounters rather than systematic survey. The recorded sites are as follows:

a. Site 5RB69

This site is on the northern edge of an alluvial terrace on the south side of the Piceance Creek valley. It faces north, 27 meters above the flood plain of Piceance Creek and is relatively distant from the bluffs. The area has been disturbed to a depth of 5 centimeters by livestock, but there is no evidence to indicate the presence of any stationary objects such as fire pits, housefloors, or storage structures. There is a good possibility that local residents have collected at least some of the artifactual material from the surface.

Six flakes comprise the total artifact yield on the site. The yield is too limited to permit any assignment of the site to a time period other than Protohistoric or earlier.

b. Site 5RB136

The site is on the crest of the ridge between Stewart Gulch and Sorghum Gulch. The site is on a fairly level ground and elevated above the surrounding terrain. It is now located in a dense stand of pinyon-juniper.

There are no visible features present on the site even though the site is relatively undisturbed. However, a few fragments of shattered bone which had been exposed to intense heating were found. The artifact yield was small. Only seven waste flakes and a single tool were found. The tool (5RB136.1) is a bifacially-flaked object with no modifications, such as notches, of the blade margins.

The absence of diagnostic artifacts from the inventory makes determination of the age of occupation or the cultural affinities of the occupants impossible.

c. Site 5RB146

The site occupies about the same topographic position as 5RB136. The exception is that there is a tributary to Stewart Gulch which has incised itself into the eastern flank of the ridge.

The site has been extensively disturbed by the chaining of the ridge tops, and its scientific and cultural values, if any, have been destroyed. Only three waste flakes could be found in the area, indicating rather limited use of the site. Two projectile points (5RB146.1 and 5RB146.3) were found. They are similar to others found in the region. One projectile point is slightly asymmetrical; one blade margin is straight, while the other is convex. No dates were assigned to this type. A single scraper fragment was also found at

the site. The site is assigned to the middle Archaic Period.

d. Site 5RB147

The site is in a ridge-top situation and has a good view of Scandard Gulch and the Tract area to the east. Because this area has been subjected to chaining, much of the site has been extensively disturbed. The site produced four waste flakes and a small fragment of knife blade or projectile point. The tool is too fragmentary to be compared with materials from other sites.

3. Cultural Resources - Euro-American Sites

Site 5RB67 is located on an alluvial fan across the bottom of Middle Fork Stewart Gulch. It consists of a cement-chinked log cabin, a dugout and a thin scatter of historic trash. An abandoned irrigation ditch also crosses the site.

The cabin is in a bad state of repair, though there are no signs of disturbance of the deposits. Materials collected include beer cans dated from the late 1940's and early 1950's, as well as pottery and glass shard. The last significant use of the site appears to have been 25 years ago. Nails used indicate the cabin was probably built no earlier than the 1920's.

4. Isolated Finds.

Several isolated finds, consisting of three projectile points, four chipped-stone tool remnants, and three ground stone tools, were also found in the study area.

5. Summary and Interpretation

Four prehistoric sites (three within the Tract and one outside), one historic site outside the Tract boundary and several isolated artifacts comprise the cultural resources found on the Tract.

The time period represented by the sites and artifacts falls roughly between 5000 B.C. and the early 1950's. This spans the Archaic and Euro-American periods. The area was first used by hunters/gatherers and then by pastoralists who raised sheep and cattle. From the foregoing information it is assumed that the Tract was only lightly occupied. The chaining of the pinyon-pine-juniper probably had deleterious effects on the fragile archaeological sites and evidence of prehistory activity was possibly destroyed by that range improvement program.

No factor in the cultural resource inventory has been found which would prevent further development of the mineral resources on the Tract according to the investigating archaeologist's report.

6. Conclusion

In summary, sites 5RB136 and 5RB146 are the only sites deemed worthy of future consideration in the development of Tract C-b. These sites will be further investigated prior to any developments which would disturb them. The other recorded sites in and near the Tract will require no further study as they either have very little potential or have already been destroyed by human or natural factors.

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